Calculating HFC and PFC Emissions from the Manufacturing, Servicing, and/or Disposal of Refrigeration and Air-Conditioning Equipment

Calculation Worksheets (Version 1.0)

Purpose and Domain of Application

This guideline is written for plant managers and site personnel to facilitate the measurement and reporting of greenhouse gas direct hydrofluorocarbon (HFC) and perfluorocarbon (PFC) 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.

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 and PFCs.

HFC and PFC 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) 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.

Choosing Activity Data and Emission Factors

HFC and PFC 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 (emissions factor based approach) and two quantification approaches, offering reporters a choice based on data availability and the level of accuracy required.

Equipment manufacturers and equipment users who maintain their own equipment are likely to find Approach 1, the "Sales-Based Approach," the most accurate and easiest to use. This approach estimates HFC and PFC emissions based on the amount of refrigerant purchased and used by the equipment manufacturer or user. The approach requires data that should be available from entity purchase and service records, and tracks emissions from manufacturing, servicing, and disposal. Spreadsheet 1a is designed for equipment manufacturers, while Spreadsheet 1b is designed for equipment users.

Equipment users who have contractors maintain their equipment may find it easier to use Approach 2, the "Life-Cycle Stage Approach." 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 contractor should be able to provide it. The Lifecycle Stage Approach provides a reasonable estimate of emissions from equipment, and tracks emissions from installation, servicing, and disposal.

Acknowledgements

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Instructions for Using the Sales-Based Approach to Calculate HFC and PFC Emissions from Manufacturing Refrigeration/AC Equipment

You will need to determine the following factors for each different refrigerant used:

- Refrigerant inventory at beginning of year (in storage, not equipment)
- Refrigerant inventory at end of year (in storage, not equipment)
- Refrigerant purchased from producers or distributors
- Refrigerant returned by equipment users
- Refrigerant returned after off-site recycling or reclamation
- Refrigerant charged into equipment (or alternatively the nameplate capacity and the full and partial density or pressure)
- Refrigerant delivered to equipment users in containers
- Refrigerant returned to refrigerant producers
- Refrigerant sent off-site for recycling or reclamation
- Refrigerant sent off-site for destruction

Step	Instructions
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.
A1	Enter into Column W the 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 1a: HFC and PFC Emissions from Refrigeration/AC Equipment: Sales Based Approach for Manufacturers

Direct Emissions

Direct emissions are emissions that are produced from the operation of any controlled or owned entity.

You will need to determine the following factors:

- Refrigerant inventory at beginning of year (in storage, not equipment)
- Refrigerant inventory at end of year (in storage, not equipment)
- Refrigerant purchased from producers or distributors
- Refrigerant returned by equipment users
- Refrigerant returned after off-site recycling or reclamation
- Refrigerant charged into equipment (or alternatively the nameplate capacity and the full and partial density or pressure)
- Refrigerant delivered to equipment users in containers
- Refrigerant returned to refrigerant producers
- Refrigerant sent off-site for recycling or reclamation
- Refrigerant sent off-site for destruction

Table 1 provides GWPs for different refrigerants as a reference.

Clearly state in the final report if different values than the default factors are used, including their source.

Cell color code:

Mandatory user entry:
Optional user entry:
Default value:
Auto calculated value:

Sales-Based Approach: Emissions from Manufacturing of Air Conditioning and Refrigeration Equipment

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11	Step 12	Step 13	Step 14	Step 15	Step 16	Step 17	Step 18	Step 19
Equipment and Refrigerant Type		Decrease in Inventory (kilograms)			Purchases/Acquisitions of Refrigerant (kilograms)				Sales/Disbursements of Refrigerant (kilograms)						Emissions			
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Type of Air Conditioning and Refrigeration Equipment	Refrigerant Used	Refrigerant inventory (in storage, not equipment) at the beginning of the year	Refrigerant inventory (in storage, not equipment) at the end of the year	Decrease in Refrigerant Inventory E = C - D	Refrigerant purchased from producers/ distributors	Refrigerant returned by equipment users	Refrigerant returned after off-site recycling or reclamation	Total Refrigerant Purchases/ Acquisitions I = F + G + H	Refrigerant charged into equipment* If full known, see steps K-N to fill in a added value	Refrigerant delivered to equipment users in containers	Refrigerant returned to refrigerant producers	Refrigerant sent off-site for recycling or reclamation	Refrigerant sent off-site for destruction	Total Refrigerant Sales/Disbursements O = J + K + L + M + N	Refrigerant Emissions (kilograms) P = E + I - O	Conversion Factor (tonnes/Kilogram)	GWP of Refrigerant See Table 1	CO2-Equivalent Emissions (tonnes) S = P x Q x R
	HFC-134a			0.00				0.00	please enter					0.00	0.00	1.00E-03	1,300	0.00E+00
	HFC-236fa			0.00				0.00	please enter					0.00	0.00	1.00E-03	6,300	0.00E+00
	R-401A			0.00				0.00	please enter					0.00	0.00	1.00E-03	18	0.00E+00
	R-402A			0.00				0.00	please enter					0.00	0.00	1.00E-03	1,680	0.00E+00
	R-402B			0.00				0.00	please enter					0.00	0.00	1.00E-03	1,064	0.00E+00
	R-402B			0.00				0.00	please enter					0.00	0.00	1.00E-03	1,064	0.00E+00
	R-404A			0.00				0.00	please enter					0.00	0.00	1.00E-03	3,260	0.00E+00
	R-407A			0.00				0.00	please enter					0.00	0.00	1.00E-03	1,770	0.00E+00
	R-407B			0.00				0.00	please enter					0.00	0.00	1.00E-03	2,285	0.00E+00
	R-407C			0.00				0.00	please enter					0.00	0.00	1.00E-03	1,526	0.00E+00
	R-410A			0.00				0.00	please enter					0.00	0.00	1.00E-03	1,725	0.00E+00
	R-507 or R-507A			0.00				0.00	please enter					0.00	0.00	1.00E-03	3,300	0.00E+00
	R-508A			0.00				0.00	please enter					0.00	0.00	1.00E-03	10,175	0.00E+00
	R-508B			0.00				0.00	please enter					0.00	0.00	1.00E-03	10,350	0.00E+00
	additional refrigerant (specify)			0.00				0.00	please enter					0.00	0.00	1.00E-03	#N/A	#N/A
	additional refrigerant (specify)			0.00				0.00	please enter					0.00	0.00	1.00E-03	#N/A	#N/A
	additional refrigerant (specify)			0.00				0.00	please enter					0.00	0.00	1.00E-03	#N/A	#N/A
	additional refrigerant (specify)			0.00				0.00	please enter					0.00	0.00	1.00E-03	#N/A	#N/A
TOTAL MANUFACTURER EMISSIONS ****																TOTAL MANUFACTURER EMISSIONS		#N/A

Please insert more rows as necessary to list additional equipment or refrigerants; if using Step A (Columns W, X, Y and Z), add rows in the appropriate place there as well.

Step A: Calculating Refrigerant Charged into Equipment

	Step A.1	Step A.2	Step A.3	Step A.4
	Refrigerant charged into equipment (kilograms)			
Refrigerant Used	Nameplate Capacity of Partially Charged Equipment W	Density or Pressure** of partial charge X	Density or Pressure** of full charge Y	Refrigerant charged into equipment Z = W/X/Y
HFC-134a				
HFC-236fa				
R-401A				
R-402A				
R-402B				
R-402B				
R-404A				
R-407A				
R-407B				
R-407C				
R-410A				
R-507 or R-507A				
R-508A				
R-508B				
additional refrigerant (specify)				
additional refrigerant (specify)				
additional refrigerant (specify)				
additional refrigerant (specify)				

FOOTNOTES:

*The quantity refrigerant charged into equipment should not include charging emissions. If the equipment is fully charged, this quantity should be the total full charge of the equipment. If the equipment is only partially charged, this quantity should be the mass of refrigerant actually charged into the equipment (if known) or the product of the total full charge and the ratio between the density of the partial and the full filling density. (The ratio of the partial and full pressures may be used instead of the ratio of the densities, as long as the pressures are compared at a constant temperature.) Manufacturers may use the spreadsheet at the right to calculate this quantity.

**If using Pressure, provide in absolute units, e.g., Pa or psia

Instructions for Using the Sales-Based Approach to Calculate HFC and PFC Emissions from Users of Refrigeration/AC Equipment

You will need to determine the following factors for each different refrigerant used:

- Refrigerant inventory at beginning of year (in storage, not equipment)
- Refrigerant inventory at end of year (in storage, not equipment)
- Refrigerant purchased from producers or distributors in bulk
- Refrigerant provided by manufacturers with or inside of equipment
- Refrigerant added to equipment by contractors
- Refrigerant returned after off-site recycling or reclamation
- Sales of bulk refrigerant to other entities
- Refrigerant left in equipment that is sold to other entities
- Refrigerant returned to suppliers
- Refrigerant sent off-site for recycling or reclamation
- Refrigerant sent off-site for destruction
- Total full charge* of new equipment using this refrigerant
- Total full charge* of equipment that is retrofitted to use this refrigerant
- Original total full charge* of retiring or sold equipment that used this refrigerant
- Total full charge* of equipment that is retrofitted away from this refrigerant to a different refrigerant

*** 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 the Guide to Calculation Worksheets, Section III.A., Approach I, for a discussion of this quantity and its importance.

Step	Instructions
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 entitites.
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 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 the Guide to Calculation Worksheets, Section III.A., Approach I, for a discussion of this quantity and its importance.

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

Direct Emissions

Direct emissions are emissions that are produced from the operation of any controlled or owned entity.

You will need to determine the following factors for each refrigerant used:

- Refrigerant inventory at beginning of year (in storage, not equipment)
- Refrigerant inventory at end of year (in storage, not equipment)
- Refrigerant purchased from producers or distributors in bulk
- Refrigerant provided by manufacturers with or inside of equipment
- Refrigerant added to equipment by contractors
- Refrigerant returned after off-site recycling or reclamation
- Sales of bulk refrigerant to other entities
- Refrigerant left in equipment that is sold to other entities
- Refrigerant returned to suppliers
- Refrigerant sent off-site for recycling or reclamation
- Refrigerant sent off-site for destruction
- Total full charge of new equipment using this refrigerant
- Total full charge of equipment that is retrofitted to use this refrigerant
- Original total full charge of retiring or sold equipment that used this refrigerant
- Total full charge of equipment that is retrofitted away from this refrigerant to a different refrigerant

Table 1 provides GWPs for different refrigerants as a reference.

Clearly state in the final report if different values than the default factors are used, including their source.

Cell color code:

Mandatory user entry:	
Optional user entry:	
Default value:	
Auto calculated value:	

Sales-Based Approach: Emissions from Users of Air Conditioning and Refrigeration Equipment

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11	Step 12	Step 13	Step 14	Step 15	Step 16	Step 17	Step 18	Step 19	Step 20	Step 21	Step 22	Step 23	Step 24	Step 25
Equipment and Refrigerant Type		Decrease in Inventory (kilograms)			Purchases/Acquisitions of Refrigerant (kilograms)					Sales/Disbursements of Refrigerant (kilograms)						Increase in Total Full Charge of Equipment (kilograms)					Emissions			
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
Type of Air Conditioning and Refrigeration Equipment	Refrigerant Used	Refrigerant inventory (in storage, not equipment) at the beginning of the year	Refrigerant inventory (in storage, not equipment) at the end of the year	Decrease in Refrigerant Inventory E = C - D	Refrigerant purchased from producers/ distributors in bulk	Refrigerant provided by manufacturers with or inside equipment	Refrigerant added to equipment by contractors	Refrigerant returned after off-site recycling or reclamation	Total Refrigerant Purchases/ Acquisitions J = F + G + H + I	Sales of refrigerant (in bulk, not in equipment) to other entities	Refrigerant left in equipment that is sold to other entities	Refrigerant returned to suppliers	Refrigerant sent off-site for recycling or reclamation	Refrigerant sent off-site for destruction	Total Refrigerant Sales/Disbursements P = K + L + M + N + O	Total full charge of new equipment	Total full charge of equipment retrofitted to use this refrigerant	Original total full charge of equipment that is retired or sold to other entities	Total full charge of equipment retrofitted away from this refrigerant to a different refrigerant	Increase in Total Full Charge of Equipment U = Q + R - S - T	Refrigerant Emissions (kilograms) V = E + J - P - U	Conversion Factor (tonnes/kilogram)	GWP of Refrigerant See Table 1	CO2-Equivalent Emissions (tonnes) Y = V x W x X
	HFC-134a			0.00					0.00						0.00					0.00	0.00	1.0OE-03	1,300	0.00E+00
	HFC-236fa			0.00					0.00						0.00					0.00	0.00	1.0OE-03	6,300	0.00E+00
	R-401A			0.00					0.00						0.00					0.00	0.00	1.0OE-03	18	0.00E+00
	R-402A			0.00					0.00						0.00					0.00	0.00	1.0OE-03	1,680	0.00E+00
	R-402B			0.00					0.00						0.00					0.00	0.00	1.0OE-03	1,064	0.00E+00
	R-403B			0.00					0.00						0.00					0.00	0.00	1.0OE-03	1,064	0.00E+00
	R-404A			0.00					0.00						0.00					0.00	0.00	1.0OE-03	3,260	0.00E+00
	R-407A			0.00					0.00						0.00					0.00	0.00	1.0OE-03	1,770	0.00E+00
	R-407B			0.00					0.00						0.00					0.00	0.00	1.0OE-03	2,285	0.00E+00
	R-407C			0.00					0.00						0.00					0.00	0.00	1.0OE-03	1,526	0.00E+00
	R-410A			0.00					0.00						0.00					0.00	0.00	1.0OE-03	1,725	0.00E+00
	R-507 or R-507A			0.00					0.00						0.00					0.00	0.00	1.0OE-03	3,300	0.00E+00
	R-508A			0.00					0.00						0.00					0.00	0.00	1.0OE-03	10,175	0.00E+00
	R-508B			0.00					0.00						0.00					0.00	0.00	1.0OE-03	10,350	0.00E+00
TOTAL USER EMISSIONS ==========																						TOTAL USER EMISSIONS			0.00E+00

Please insert more rows as necessary to list additional refrigerants.

Instructions for Using the Lifecycle Stage Approach to Calculate HFC and PFC Emissions from Users of Refrigeration/AC Equipment

You will need to determine the following factors for each different refrigerant used:

- Refrigerant used to fill new equipment
- Refrigerant used to fill equipment retrofitted to use this refrigerant
- Total full charge* of new equipment using this refrigerant
- Total full charge* of equipment that is retrofitted to use this refrigerant
- Refrigerant used to service equipment
- Total original full charge* of retiring equipment
- Total original full charge* of equpment that is retrofitted away from this refrigerant to a different refrigerant
- Refrigerant recovered from retiring equipment
- Refrigerant recovered from equipment that is retrofitted away from this refrigerant to a different refrigerant

***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 the Guide to Calculation Worksheets, Section III.A., Approach 1, for a discussion of this quantity and its importance.

Step	Instructions
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 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 the Guide to Calculation Worksheets, Section III.A., Approach 2, for a discussion of this quantity and its importance.

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

Direct Emissions

Direct emissions are emissions that are produced from the operation of any controlled or owned entity.

You will need to determine the following factors for each refrigerant used:

- Refrigerant used to fill new equipment
- Refrigerant used to fill equipment retrofitted to use this refrigerant
- Total full charge of new equipment using this refrigerant
- Total full charge of equipment that is retrofitted to use this refrigerant
- Refrigerant used to service equipment
- Total original full charge of retiring equipment
- Total original full charge of equipment that is retrofitted away from this refrigerant to a different refrigerant
- Refrigerant recovered from retiring equipment
- Refrigerant recovered from equipment that is retrofitted away from this refrigerant to a different refrigerant

Table 1 provides GWPs for different refrigerants as a reference.

Clearly state in the final report if different values than the default factors are used, including their source.

Cell color code:

Mandatory user entry:	
Optional user entry:	
Default value:	
Auto calculated value:	

Lifecycle Stage Approach: Emissions from Users of Air Conditioning and Refrigeration Equipment

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11	Step 12	Step 13	Step 14	Step 15	Step 16	Step 17
Equipment and Refrigerant Type		**Installation Emissions (kilograms)**					**Use Emissions (kg)**	**Final Use and Disposal Emissions (kilograms)**					**Emissions**			
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Type of Air Conditioning and Refrigeration Equipment	**Refrigerant Used**	**Refrigerant used to fill new equipment**	**Refrigerant used to fill equipment retrofitted to use this refrigerant**	**Total full charge of new equipment using this refrigerant**	**Total full charge of equipment retrofitted to use this refrigerant**	**Total Installation Emissions** G = C + D - E - F	**Refrigerant used to service equipment (net amount after recovery, recycling and recharge)**	**Original total full charge of equipment that is retired or sold to other entities**	**Total original full charge of equipment retrofitted away from this refrigerant to a different refrigerant**	**Refrigerant recovered from retiring equipment**	**Refrigerant recovered from equipment retrofitted away from this refrigerant to a different refrigerant**	**Total Final Use and Disposal Emissions** M = I + J - K - L	**Refrigerant Emissions (kilograms)** N = G + H + M	**Conversion Factor (tonnes/kilogram)**	**GWP of Refrigerant** See Table 1	**CO2-Equivalent Emissions (tonnes)** Q = N x O x P
	HFC-134a					0.00						0.00	0.00	1.00E-03	1,300	0.00E+00
	HFC-236fa					0.00						0.00	0.00	1.00E-03	6,300	0.00E+00
	R-401A					0.00						0.00	0.00	1.00E-03	18	0.00E+00
	R-402A					0.00						0.00	0.00	1.00E-03	1,680	0.00E+00
	R-402B					0.00						0.00	0.00	1.00E-03	1,064	0.00E+00
	R-402B					0.00						0.00	0.00	1.00E-03	1,064	0.00E+00
	R-404A					0.00						0.00	0.00	1.00E-03	3,260	0.00E+00
	R-407A					0.00						0.00	0.00	1.00E-03	1,770	0.00E+00
	R-407B					0.00						0.00	0.00	1.00E-03	2,285	0.00E+00
	R-407C					0.00						0.00	0.00	1.00E-03	1,526	0.00E+00
	R-410A					0.00						0.00	0.00	1.00E-03	1,725	0.00E+00
	R-507 or R-507A					0.00						0.00	0.00	1.00E-03	3,300	0.00E+00
	R-508A					0.00						0.00	0.00	1.00E-03	10,175	0.00E+00
	R-508B					0.00						0.00	0.00	1.00E-03	10,350	0.00E+00
	additional refrigerant (specify:)					0.00						0.00	0.00	1.00E-03	#N/A	#N/A
	additional refrigerant (specify:)					0.00						0.00	0.00	1.00E-03	#N/A	#N/A
	additional refrigerant (specify:)					0.00						0.00	0.00	1.00E-03	#N/A	#N/A
	additional refrigerant (specify:)					0.00						0.00	0.00	1.00E-03	#N/A	#N/A
TOTAL USER EMISSIONS ==========>														**TOTAL USER EMISSIONS**		**#N/A**

Please insert more rows as necessary to list additional refrigerants.

Instructions for Using Worksheet 3: Emission Factor-Based Approach to Estimate HFC and PFC Emissions from Refrigeration/AC

You will need to determine the following factors:

- Type of Equipment
- Number of Units
- Refrigerant Used
- GWP of the Refrigerant
- Total Refrigerant Charge for the Equipment (kg)
- Assembly Emission Factor (%)
- Annual Leakage Rate (%)
- Recovery (%)
- Refrigerant Destroyed (kg)
- Equipment Lifetime (years)

Table 1 provides GWPs for different refrigerants as a reference.
Table 2 provides default lifetimes, assembly emission factors, annual leakage rates, and recycling efficiency values from IPCC Good Practice.

Step 1. Assembly/Installation Emissions

1.1 Enter the type of Refrigeration/AC equipment in Column A (Optional)
1.2 Enter the number of units produced (manufacturers) or installed (users) 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. Default values for various applications 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 reporting period 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 or fraction thereof) since last recharge in Column G.
3.8 Enter the percentage of refrigerant recycled of refrigeration/AC equipment in Column H. Default values for various applications have been provided in Table 2.
3.9 Enter the amount of refrigerant sent for destruction (kg) during the current period in Column I. If more than one type of equipment uses the same refrigerant, enter only the refrigerant sent for destruction that was recovered from the given equipment type. If only a total is known, enter it in only one row of that given refrigerant.
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).

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

Direct Emissions

Direct emissions are those that are produced from sources owned or controlled by the reporting entity.

You will need to determine the following factors:

Table 1 provides GWPs for different refrigerants as a reference.
Table 2 provides default lifetimes, assembly leak rates, annual leak rates, and disposal recovery factors from IPCC Good Practice.

Clearly state in the final report if different values than the default factors are used, including their source.

Cell color code:
Mandatory user entry:
Optional user entry:
Default value:
Auto calculated value:

Step 1: Determine Annual Net HFC and PFC Emissions from Assembly/Installation of Refrigeration/AC Equipment

Step 1.1	Step 1.2	Step 1.3	Step 1.4	Step 1.5	Step 1.6		Step 1.7
A	B	C	D	E	F	G	H
Refrigeration/Air-Conditioner Equipment Name	**Number of Units**	**Type of Refrigerant**	**GWP of Refrigerant**	**Original Refrigerant Charge in Each Unit (kilograms)**	**Assembly/Installation Emission Factor**	**Conversion Factor (tonnes/kilograms)**	**Assembly Emissions (tonnes of CO2 equivalent/yr)**
Optional		Optional	See Table 1	See Table 2	See Table 2		B x D x E x F x G
						1.00E-03	-
						1.00E-03	-
						1.00E-03	-
						1.00E-03	-
						1.00E-03	-
						1.00E-03	-
Total							-

Please insert more rows as necessary.

Please insert more rows for equipment types as necessary.

Step 2: Determine Net Gross HFC and PFC Emissions from Operation of Refrigeration/AC Equipment

Step 2.1	Step 2.2	Step 2.3	Step 2.4	Step 2.5	Step 2.6		Step 2.7
A	B	C	D	E	F	G	H
Refrigeration/Air-Conditioner Equipment Name	**Number of Units**	**Type of Refrigerant**	**GWP of Refrigerant**	**Refrigerant Charge (kilograms)**	**Annual Leakage Rate (%)**	**Conversion Factor (tonnes/kilograms)**	**Operation Emissions (tonnes of CO2 equivalent/yr)**
Optional		Optional	See Table 1	See Table 2	See Table 2		B x D x E x F x G
						1.00E-03	-
						1.00E-03	-
						1.00E-03	-
						1.00E-03	-
						1.00E-03	-
						1.00E-03	-
Total							-

Please insert more rows as necessary.

Step 3: Determine Annual Net HFC and PFC Emissions from Disposal of Refrigeration/AC Equipment

Step 3.1	Step 3.2	Step 3.3	Step 3.4	Step 3.5	Step 3.6	Step 3.7	Step 3.8	Step 3.9		Step 3.10
A	B	C	D	E	F	G	H	I	J	K
Refrigeration/Air-Conditioner Equipment Name	**Number of Units**	**Type of Refrigerant**	**GWP of Refrigerant**	**Original Refrigerant Charge (kilograms)**	**Annual Leakage Rate (%)**	**Time since last recharge (years)**	**Recycling Efficiency (%)**	**Destruction (kilograms)**	**Conversion Factor (tonnes/kilograms)**	**Disposal Emissions (tonnes of CO2 equivalent/yr)**
Optional			See Table 1	See Table 2	See Table 2		See Table 2			((B x E) x (1 - (F * G)) x (1 - H)-I)* D * J
									1.00E-03	-
									1.00E-03	-
									1.00E-03	-
									1.00E-03	-
									1.00E-03	-
									1.00E-03	-
Total										-

Please insert more rows as necessary.

Step 4: Determine Annual Net HFC and PFC Emissions

Step 4.1	Step 4.2	Step 4.3	Step 4.4
A	B	C	D
Assembly Emissions	**Operation Emissions**	**Disposal Emissions**	**Total Emissions (tonnes of CO2 Equivalent)**
Result of Step 1	Result of Step 2	Result of Step 3	A + B + C
-	-	-	-

Table 1. GWPs of Common Greenhouse Gases and Refrigerants

Gas or Blend	GWP	Source
CO2*	1	IPCC Second Assessment Report (1995)
CH4*	21	IPCC Second Assessment Report (1995)
N2O*	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 (C3F8)	7,000	UNEP OzonAction Programme Chemical Database (Online)
PFC-116 (C2F6)	9,200	IPCC Second Assessment Report (1995)
PFC-14 (CF4)	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 (CO2, CH4, HFC, PFC, SF6, N20).

Table 2. Default Assumptions from IPCC Good Practice Guidelines*

Application	Charge (kg)	Lifetime (years)	Emission Factors (% of initial charge/yr)		
			Assembly	Annual Leakage Rate	Recycling Efficiency
Domestic Refrigeration	0.05 - 0.5	12 - 15	0.2 - 1 %	0.1 - 0.5 %	70% of remainder
Stand-Alone Commercial Applications	0.2 - 6	8 - 12	0.5 - 3 %	1 - 10 %	70 - 80% of the remainder
Medium and Large Commercial refrigeration	50 - 2000	7 - 10	0.5 - 3 %	10 - 30 %	80 - 90% of remainder
Transport Refrigeration	3.0 - 8.0	6 - 9	0.2 - 1 %	15 - 50 %	70 - 80% of remainder
Industrial Refrigeration including Food Processing and Cold Storage	10 - 10000	10 - 20	0.5 - 3 %	7 - 25 %	80 - 90% of remainder
Chillers	10.0 - 2000	10 - 30	0.2 - 1 %	2 - 15 %	80 - 95% of remainder
Residential and Commercial A/C, including Heat Pumps	0.5 - 100	10 - 15	0.2 - 1 %	1 - 5 %	70 - 80% of remainder
Mobile Air Conditioners	Not provided	12	0.50%	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