Greenhouse Gas Inventory Guidance

Direct Fugitive Emissions from Refrigeration, Air Conditioning, Fire Suppression, and Industrial Gases

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The U.S. EPA Center for Corporate Climate Leadership's (The Center) GHG guidance is based on The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (GHG Protocol) developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The Center's GHG guidance is meant to extend upon the GHG Protocol to align more closely with EPA-specific GHG calculation methodologies and emission factors, and to support the Center's GHG management tools and its Climate Leadership Awards initiative.

For more information regarding the Center for Corporate Climate Leadership, visit www.epa.gov/climateleadership.

Table of Contents

Section 1: Introduction 1

1.1. Greenhouse Gases Included 2

1.2. Manufacturing vs. Use Phase Emissions....2

Section 2: Methods for Calculating Emissions 5

2.1. Screening Method....6

2.1.1 Refrigeration and Air Conditioning Equipment Screening 6

2.1.2 Fire Suppression Equipment Screening 7

2.2. Method for Purchased Gases....8

2.3. Material Balance Method 8

2.4. Simplified Material Balance Method 10

Section 3: Choice of Activity and Emission Factors....11

3.1. Screening Method....11

3.2. Method for Purchased Gases....12

3.3. Material Balance Method 12

3.4. Simplified Material Balance Method 13

Section 4: Completeness 14

Section 5: Uncertainty Assessment....15

Section 6: Documentation....16

Section 7: Inventory Quality Assurance and Quality Control (QA/QC)....17

Section 1: Introduction

An important category of Scope 1 direct greenhouse gas (GHG) are fugitive emissions, which result from the direct release to the atmosphere of GHG compounds from various types of equipment and processes. This guidance document focuses on several fugitive emissions sources that are common for organizations in many sectors: refrigeration and air conditioning systems, fire suppression systems, and the purchase and release of industrial gases.

Historically, air conditioning and refrigeration equipment utilized various Ozone Depleting Substances (ODSs), primarily chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). However, in accordance with the Clean Air Act Amendments of 1990 (Title VI) and the Montreal Protocol, these ODSs are being phased out of manufacture and use in the United States.

Hydrofluorocarbons (HFCs) and, to a lesser extent, perfluorocarbons (PFCs) are used as substitutes for the regulated ODSs. In addition, some air conditioning and refrigeration systems use non-halogenated refrigerants such as ammonia, carbon dioxide (CO_2), propane, or isobutane. Also, some fire suppression equipment, which historically used ozone-depleting halons, use carbon dioxide (CO_2), inert gases, and other substances.

Emissions from the refrigeration and air conditioning sector result from the manufacturing process, from leakage and service 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 (GWPs), which are typically greater than 1,000 times that of CO_2, so their potential impact on climate change can be significant (see examples in Table 1). By the same token, any reductions of these gases can have a large potential benefit.

This guidance document addresses the following:

- Emissions from users of refrigeration and air conditioning equipment 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.
- Emissions from fixed and portable fire suppression equipment.
- Direct emissions from purchased industrial gases. These gases can be used in processes such as manufacturing, testing, or laboratory applications.

Emissions from aerosols, solvent cleaning, foam blowing, or other applications are not addressed by this protocol.

1.1. Greenhouse Gases Included

The emissions sources addressed by this guidance document could result in emissions of any of the GHGs included in Table 1.

Ozone depleting substances include a number of different compounds such as CFCs, HCFCs, and halons, all of which have global warming potentials. As mentioned, these ODSs are being phased out of production due to their ozone depleting properties. However, some entities may still use these substances directly or in blends within refrigeration, air conditioning, or fire suppression equipment.

It is customary to exclude CFCs, HCFCs, and halons from GHG inventories because they are regulated and are being phased out by the Clean Air Act. These substances are also excluded from GHG inventories because their global warming potentials are complicated by the fact that they deplete stratospheric ozone, which is a greenhouse gas. The GHG Protocol allows for reporting of these ODSs as separate memo items on an organization's GHG inventory. They are reported as total release of gases but no global warming potentials are applied and they do not contribute to an organization's total CO_2-equivalent emissions inventory. Therefore, organizations that currently use ODSs and switch to HFCs or PFCs may show an increase in their overall GHG emissions inventory. Documenting the use of these ODSs will help communicate the reasons for this increase.

1.2. Manufacturing vs. Use Phase Emissions

This document only applies to Scope 1 GHG emissions resulting from operations at the reporting organization's facilities. For refrigeration, air conditioning, and fire suppression equipment, these emissions may take place during the installation, use, or disposal. Refrigerants and fire suppressants may be released from equipment leaks throughout their operating life or from catastrophic leaks. Also, when equipment is installed, repaired, or removed, refrigerants and fire suppressants may be released if proper recovery processes are not used. Fire suppressants are also emitted to extinguish fires. Emissions that occur during the manufacturing or disposal of equipment or purchased gases are Scope 3 indirect emissions, and are not included in an organization's Scope 1 emissions.

Table 1: Global Warming Potentials

Common Name	**Formula**	**GWP***
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
Sulfur hexafluoride	SF_6	22,800
Nitrogen trifluoride	NF_3	17,200
HFC-23	CHF_3	14,800
HFC-32	CH_2F_2	675
HFC-41	CH_3F	92
HFC-125	C_2HF_5	3,500
HFC-134	CHF_2CHF_2	1,100
HFC-134a	$C_2H_2F_4$	1,430
HFC-143	CH_2FCHF_2	353
HFC-143a	$C_2H_3F_3$	4,470
HFC-152	CH_2FCH_2F	53
HFC-152a	$C_2H_4F_2$	124
HFC-161	CH_3CH_2F	12
HFC-227ea	C_3HF_7	3,220
HFC-236cb	$CH_2FCF_2CF_3$	1,340
HFC-236ea	CHF_2CHFCF_3	1,370
HFC-236fa	$C_3H_2F_6$	9,810
HFC-245ca	$CH_2FCF_2CHF_2$	693
HFC-245fa	$CHF_2CH_2CF_3$	1,030
HFC-365mfc	$CH_3CF_2CH_2CF_3$	794
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	1,640
PFC-14	CF_4	7,390
PFC-116	C_2F_6	12,200
PFC-218	C_3F_8	8,830
PFC-318	$c\text{-}C_4F_8$	10,300
PFC-3-1-10	C_4F_{10}	8,860
PFC-4-1-12	C_5F_{12}	9,160
PFC-5-1-14	C_6F_{14}	9,300
PFC-9-1-18	$C_{10}F_{18}$	>7,500

*100-year GWPs from Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (2007)

Table 2: GWPs for Refrigerant Blends

ASHRAE #	Blend Composition	GWP*
R-401A	53% HCFC-22 , 34% HCFC-124 , 13% HFC-152a	16
R-401B	61% HCFC-22 , 28% HCFC-124 , 11% HFC-152a	14
R-401C	33% HCFC-22 , 52% HCFC-124 , 15% HFC-152a	19
R-402A	38% HCFC-22 , 6% HFC-125 , 2% propane	2,100
R-402B	6% HCFC-22 , 38% HFC-125 , 2% propane	1,330
R-403B	56% HCFC-22 , 39% PFC-218 , 5% propane	3,444
R-404A	44% HFC-125 , 4% HFC-134a , 52% HFC 143a	3,922
R-406A	55% HCFC-22 , 41% HCFC-142b , 4% isobutane	0
R-407A	20% HFC-32 , 40% HFC-125 , 40% HFC-134a	2,107
R-407B	10% HFC-32 , 70% HFC-125 , 20% HFC-134a	2,804
R-407C	23% HFC-32 , 25% HFC-125 , 52% HFC-134a	1,774
R-407D	15% HFC-32 , 15% HFC-125 , 70% HFC-134a	1,627
R-407E	25% HFC-32 , 15% HFC-125 , 60% HFC-134a	1,552
R-408A	47% HCFC-22 , 7% HFC-125 , 46% HFC 143a	2,301
R-409A	60% HCFC-22 , 25% HCFC-124 , 15% HCFC-142b	0
R-410A	50% HFC-32 , 50% HFC-125	2,088
R-410B	45% HFC-32 , 55% HFC-125	2,229
R-411A	87.5% HCFC-22 , 11 HFC-152a , 1.5% propylene	14
R-411B	94% HCFC-22 , 3% HFC-152a , 3% propylene	4
R-413A	88% HFC-134a , 9% PFC-218 , 3% isobutane	2,053
R-414A	51% HCFC-22 , 28.5% HCFC-124 , 16.5% HCFC-142b	0
R-414B	5% HCFC-22 , 39% HCFC-124 , 9.5% HCFC-142b	0
R-417A	46.6% HFC-125 , 5% HFC-134a , 3.4% butane	2,346
R-422A	85.1% HFC-125 , 11.5% HFC-134a , 3.4% isobutane	3,143
R-422D	65.1% HFC-125 , 31.5% HFC-134a , 3.4% isobutane	2,729
R-423A	47.5% HFC-227ea , 52.5% HFC-134a	2,280
R-424A	50.5% HFC-125, 47% HFC-134a, 2.5% butane/pentane	2,440
R-426A	5.1% HFC-125, 93% HFC-134a, 1.9% butane/pentane	1,508
R-428A	77.5% HFC-125 , 2% HFC-143a , 1.9% isobutane	3,607
R-434A	63.2% HFC-125, 16% HFC-134a, 18% HFC-143a, 2.8% isobutane	3,245
R-500	73.8% CFC-12 , 26.2% HFC-152a , 48.8% HCFC-22	32
R-502	48.8% HCFC-22 , 51.2% CFC-115	0
R-504	48.2% HFC-32 , 51.8% CFC-115	325
R-507	5% HFC-125 , 5% HFC143a	3,985
R-508A	39% HFC-23 , 61% PFC-116	13,214
R-508B	46% HFC-23 , 54% PFC-116	13,396

* 100-year GWPs from Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (2007). GWPs of blended refrigerants are based on their HFC and PFC constituents, which are based on data from http://www.epa.gov/ozone/snap/refrigerants/refblend.html.

Section 2: Methods for Calculating Emissions

Most large organizations will have emissions from refrigeration and air conditioning equipment in one form or another. However, the potential emissions sources and level of data available may differ greatly. For instance, a supermarket chain with large refrigeration systems may have on-site storage of refrigerants and track detailed data concerning refrigerant use, while an industrial organization may simply use air conditioning in its office space and not track detailed data on refrigerant use. Often organizations whose core business does not include the use of this type of equipment exclude the associated GHG emissions from their GHG inventory as not material. However, the materiality of a source can only be established after it has been assessed. This does not necessarily require a rigorous quantification of all sources, but at a minimum, an estimate based on available data should be developed for all sources of emissions.[1]

Four methods with varying levels of accuracy and data collection required are outlined in this guidance to calculate GHG emissions. Organizations may calculate fugitive GHG emissions from refrigeration and air conditioning equipment, fire suppression systems, or purchased industrial gases with one of the following methods.

Section 2.1 describes a preliminary Screening Method to estimate emissions from refrigeration, air conditioning, and fire suppression equipment based on the type of equipment used and emission factors. This method requires the least actual data collection and is not applicable for quantifying emissions from purchased gases. It is recommended that this method be used only as a screening tool because the emissions factors used in the approach are highly uncertain. Emission factors vary between individual pieces of equipment and also vary over time. Even if the amount of refrigerant added to a piece of equipment has been tracked carefully, allowing the previous leak rate of that equipment to be established, that leak rate can change after a leak is repaired or as the equipment ages. If emissions from this equipment are determined to be significant when compared to an organization's other emission sources (e.g., stationary combustion, mobile sources), then one of the other methods should be applied to calculate emissions more accurately.

Section 2.2 describes a Method for Purchased Gases which applies to an organization that purchases, uses, and releases industrial gases. If an organization maintains an inventory of industrial gases or uses equipment that maintains a charge of an industrial gas, similar to a charge of refrigerant in air conditioning equipment, it is recommended that one of the material balance methods then be used.

Section 2.3 describes a Material Balance Method of calculating emissions from the installation, operation, and disposal of refrigeration and air conditioning equipment use. This method is recommended for organizations that maintain their own equipment and requires available data on the total inventory of refrigerants at the beginning and end of the reporting period, purchases during the reporting period, and changes in total equipment refrigerant capacity. This material balance method can also be used to calculate emissions from fire suppression equipment.

Section 2.4 describes a Simplified Material Balance Method that is appropriate for entities that do not maintain and track a stock of refrigerants, and that have not retrofitted equipment to use a different refrigerant during the reporting period. This method is recommended for organizations that have contractors service their refrigerant-containing equipment. This method tracks emissions from equipment installation, operation, and disposal. The method requires data on the quantity

[1] See Chapter 1 of the GHG Protocol for more on materiality and significance of emissions sources.

of refrigerant: (a) used to fill new equipment during installation, (b) used to service equipment, and (c) recovered from retiring equipment, as well as the total refrigerant capacities of new and retiring equipment. If notified in advance of the need for this information, the service contractor should be able to provide it.

2.1. Screening Method

The method relies on the use of emission factors which are equipment specific. Therefore, this protocol provides two different methods, one for refrigeration and air conditioning equipment and a second for fire suppression equipment. This method is not applicable for quantifying emissions from purchased gases.

2.1.1 Refrigeration and Air Conditioning Equipment Screening

Under this approach, an organization multiplies the amount of refrigerant in the equipment by an emission factor for the specific type of equipment and emission event. The disadvantage to using this approach is that emission factors are highly uncertain. Therefore, this method is proposed as a screening test only. Consequently, if an organization determines that emissions from refrigeration and air conditioning equipment may be significant, it is recommended that one of the other methods then be used. Estimating emissions with the Screening Method requires the following steps:

Step 1: Perform an inventory of equipment.
Determine the number and types of refrigeration and air conditioning equipment (by equipment category, see Section 3.1) including the types of refrigerant used and the total refrigerant capacity of each piece of equipment.

Step 2: Determine installation emissions.
Identify any new equipment that was installed during the reporting period and was charged on-site. Emissions from equipment that was charged at the manufacturer are not the responsibility of the reporting organization for equipment use (see Section 1.2). For each new piece of equipment, use Equation 1 to estimate emissions.

Step 3: Determine operating emissions.
This step estimates losses from equipment leaks and service losses over the life of the equipment. For all pieces of equipment, use Equation 2 to estimate emissions.

Equation 1: Estimating Emissions from Installation

$$\text{Emissions from Installation} = C_N \times (k/100)$$

where:

C_N = amount of refrigerant charged into the new piece of equipment

k = assembly losses in percent of amount charged

Equation 2: Estimating Emissions from Operation

$$\text{Emissions from Operation} = C \times (x/100) \times T$$

where:

C = refrigerant capacity of the piece of equipment

x = annual leak rate in percent of capacity

T = time in years used during the reporting period (e.g., 0.5 if used only during half of the reporting period and then disposed)

Step 4: Determine disposal emissions.
Identify any pieces of equipment that were disposed of during the reporting period. For each piece of disposed equipment, use Equation 3 to estimate emissions.

Step 5: Determine total emissions.
Add the emissions from each piece of equipment for each type of emission (installation, operation, and disposal) to get total emissions. Calculate separate totals for each type of refrigerant used. Multiply the emissions of each refrigerant by the refrigerant's GWP from Table 1 or Table 2 to calculate CO_2 equivalent emissions.

Section 3.1 provides default emission factors and describes the different categories of equipment for which there are default factors.

Equation 3: Estimating Emissions from Disposal

Emissions from Disposal =

$$CD \times (y/100) \times (1 - z/100)$$

where:

CD = refrigerant capacity of the piece of equipment being disposed of

y = percent of the capacity remaining at disposal

z = percent of refrigerant recovered

2.1.2 Fire Suppression Equipment Screening

Fire suppression equipment can be divided into two broad categories, fixed and portable equipment. This Screening Method provides an emission factor for each type of equipment. Under this approach, the organization multiplies the capacity of the equipment by an emission factor for fixed or portable equipment. If an organization determines that emissions from fire suppression equipment may be significant, it is recommended that one of the other methods then be used. Estimating emissions with the Screening Method requires the following steps:

Step 1: Perform an inventory of equipment.
Determine the number and types of fire suppression equipment, by gas type, and the fire suppressant capacity of each piece of equipment.

Step 2: Determine total emissions.
Add the capacities of each portable unit for each gas and of each fixed unit for each gas and multiply the total capacity by the appropriate emission factor. Emissions from fixed systems are assumed to be 2.5 percent (0.025) of the total capacity of the units for each gas. Emissions from portable equipment are assumed to be 3.5 percent (0.035) of the total capacity of the units for each gas. The emission factors provided for this Screening Method are as provided in the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012. Multiply the emissions of each fire suppressant by its GWP from Table 1 or Table 2 to calculate CO_2 equivalent emissions.

2.2. Method for Purchased Gases

Industrial gases are sometimes used in processes such as manufacturing, testing, or laboratory uses. For example, CO_2 gas is often used in welding operations. These gases are typically released to the atmosphere after use. Any use and release of the seven major GHGs (CO_2, CH_4, N_2O, PFCs, HFCs, SF_6, and NF_3) is required to be included in the GHG inventory.

Step 1: Determine purchases of industrial gases.
Determine whether any GHGs are used in processes such as those mentioned above. If so, collect the mass of each gas purchased. If data are not available in mass units, the organization may need to convert from volume to mass using the density of the specific gas. It is assumed that all gas purchased in the reporting period is used and released during the reporting period. If the organization makes a bulk purchase and plans on using the gas over multiple years, divide the bulk amount by the expected years of usage and consider that to be the purchase amount for the current reporting period, as well as the applicable future reporting periods.

Step 2: Calculate emissions.
Sum the amount of gas purchased for each gas type. Multiply the total by the appropriate GWP from Table 1 or Table 2 to calculate CO_2 equivalent emissions.

2.3. Material Balance Method

The Material Balance Method tracks emissions of refrigerants[2] from equipment through a mass balance analysis. Releases of refrigerants can be calculated based on the inventory (in storage, not in operating equipment), purchases and sales of refrigerants, as well as changes in total refrigerant capacity of equipment during the emissions reporting period. The inventory should be tracked at the facility level by type of refrigerant. Equation 4 shows the basic principles involved in this approach.

Equation 4 can be rewritten to more easily calculate emissions as shown in Equation 5.

Equation 5 should be applied to each type of refrigerant used. Calculating emissions with the Material Balance Method requires the following steps for each type of refrigerant:

Step 1: Calculate the change in inventory (I_B - I_E).
Subtract the amount of refrigerant in inventory at the end of the reporting period from the amount

Equation 4: Material Balance of Refrigerant

$$I_B + P + C_B = I_E + S + C_E + \text{Emissions}$$

where:

I_B = refrigerant in inventory (in storage, not in operating equipment) at the beginning of reporting period

P = refrigerant purchased or otherwise acquired during the reporting period

C_B = total refrigerant capacity of equipment at the beginning of the reporting period

I_E = refrigerant in inventory (in storage, not in operating equipment) at the end of reporting period

S = refrigerant sold or otherwise disposed of during the reporting period

C_E = total refrigerant capacity of equipment at the end of the reporting period

Equation 5: Calculating Refrigerant Emissions with the Material Balance Method

$$\text{Emissions} = (I_B - I_E) + P - S + (C_B - C_E)$$

[2] The term "refrigerant" is used in this section, but this method can also apply to fire suppressants or industrial gases.

in inventory at the beginning of the reporting period to calculate the change in inventory. The inventory of refrigerants is defined as the total stored on site in cylinders or other storage. This does not include refrigerants contained within equipment.

Step 2: Determine purchases and other acquisitions (P).

Purchases and other acquisitions may include refrigerant: (a) purchased from producers or distributors, (b) provided by manufacturers with or inside equipment, (c) added to equipment by contractors or other service personnel (but not if that refrigerant is from the organization's inventory), and (d) returned after off-site recycling or reclamation.

Step 3: Determine sales and disbursements (S).

Sales and disbursements may include refrigerant: (a) in containers or left in equipment that is sold or disposed of, (b) returned to suppliers, and (c) sent off-site for recycling, reclamation, or destruction. The amount of refrigerant left in equipment should be the actual amount, which may be less than the total capacity.

Step 4: Calculate the change in capacity (C_B - C_E).

The change in capacity is the net change to the total equipment volume for a given refrigerant during the reporting period. Note that "total capacity" refers to the full and proper charge of the equipment rather than the actual charge, which may reflect leakage. Because the material balance is performed for each refrigerant individually, retrofitting of equipment to use a different refrigerant will represent a change in capacity for the old and the new refrigerant. If the beginning and ending total capacity values are not known, the change in capacity can be calculated based on the capacities of known installations and disposals of equipment. If an organization only installs equipment during the reporting period, C_E will be greater than C_B. The reverse is true for an organization that only disposes of equipment during the reporting period.

Step 5: Calculate emissions.

Once the previous four steps have been completed, GHG emissions for each type of refrigerant and blend may be quantified using Equation 5. Multiply the emissions of each refrigerant by the refrigerant's GWP from Table 1 or Table 2 to calculate CO_2 equivalent emissions.

Section 3.3 describes in more detail the type of data that is used in determining emissions.

It may be illustrative to describe how the installation or disposal of equipment impacts the Material Balance Method's calculation. If equipment is installed, the refrigerant capacity of that equipment is included in both term P as an acquisition and in term C_E as capacity at the end of the year. As a result, the installation has no net impact on emissions.

If equipment is disposed, the refrigerant capacity of that equipment is included in term C_B, as capacity at the beginning of the year, and the actual amount of refrigerant contained in the equipment upon disposal is included in term S as a disposition. If the amount of refrigerant contained in the equipment upon disposal equals its refrigerant capacity, the disposal will have no net impact on emissions. If the actual amount is less than the capacity, the difference is assumed to represent emissions.

2.4. Simplified Material Balance Method

The Simplified Material Balance Method is a simplified version of the Material Balance Method described above. In the simplified method, there are fewer flows of refrigerant[3] to consider. This method is appropriate for entities that do not maintain and track a stock of refrigerants, and that have not retrofitted equipment to use a different refrigerant during the reporting period. This method requires information on the quantity of refrigerant: (a) used to fill any new equipment installed during the reporting period, (b) used to service equipment, and (c) recovered from any equipment retired during the reporting period. It also requires information on the total refrigerant capacity of installed and retired equipment. This method can be summarized by Equation 6.

Equation 6: Calculating Refrigerant Emissions with the Simplified Material Balance Method

$$\text{Emissions} = (P_N - C_N) + P_S + (C_D - R_D)$$

where:

P_N = purchases of refrigerant used to charge new equipment (omitted if the equipment has been pre-charged by the manufacturer)

C_N = total refrigerant capacity of the new equipment (omitted if the equipment has been pre-charged by the manufacturer)

P_S = purchases of refrigerant used to service equipment

C_D = total refrigerant capacity of retiring equipment

R_D = refrigerant recovered from retiring equipment

Equation 6 should be applied to each type of refrigerant used. Calculating emissions with the Simplified Material Balance Method requires the following steps for each type of refrigerant:

Step 1: Calculate installation emissions (P_N - C_N).
This step is only necessary if the reporting entity installed any new equipment during the reporting period that was not pre-charged by the equipment supplier. Emissions are calculated by taking the difference between the amount of refrigerant used to charge the equipment and the total capacity of the equipment. The difference is assumed to represent emissions.

Step 2: Determine operating emissions (P_S).
Operating emissions result from equipment leaks and service losses. It is assumed that the amount of refrigerant purchased to service equipment is replacing the same amount that was emitted during operation.

Step 3: Calculate disposal emissions (C_D - R_D).
This step is only necessary if the organization disposed of equipment during the reporting period. Emissions are calculated by taking the difference between the total capacity of the equipment disposed and the amount of refrigerant recovered. The difference is assumed to represent emissions.

Step 4: Calculate emissions.
Emissions for each type of refrigerant and blend are calculated by summing the results of the first three steps. Multiply the emissions of each refrigerant by the refrigerant's GWP from Table 1 or Table 2 to calculate CO_2 equivalent emissions.

Section 3.3 describes in more detail the type of data that is used in determining emissions.

[3] The term "refrigerant" is used in this section, but this method can also apply to fire suppressants or industrial gases.

Section 3: Choice of Activity and Emission Factors

Required data for all emission estimation methods can come from inventory records, purchase records, repair reports, service records, and disposal records.

3.1. Screening Method

The Screening Method requires organizations to determine the following information:

- Type of Equipment
- Number of Units
- Refrigerant or Fire Suppressant Used
- Total Refrigerant or Fire Suppressant Charge for the Equipment (lb.)

For refrigeration and air conditioning equipment, the additional information is required:

- Assembly Emission Factor (%)
- Annual Leakage Rate (%)
- Percent of Capacity Remaining at Disposal (%)
- Recovery Efficiency (%)

The Screening Method is based on the Tier 2 approach from the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories.

The IPCC guidelines also include a table of emission factors for the different phases of the equipment's life by equipment type. The IPCC table provides ranges of values for the different emission factors, the percent remaining at disposal, and the recovery efficiency. However, since this method is intended as a screening approach, it is recommended that the upper end of the ranges be used. These values are provided in Table 3. The ranges in capacity are provided only for reference; organizations should use the actual capacity of their equipment.

Table 3: Default Emission Factors for Refrigeration/Air Conditioning Equipment

Type of Equipment	Capacity (kg)	Installation Emission Factor k (% of capacity)	Operating Emissions x (% of capacity/yr.)	Refrigerant Remaining at Disposal y (% of capacity)	Recovery Efficiency z (% of remaining)
Domestic Refrigeration	0.05–0.5	1	0.5	80	70
Stand-alone Commercial Applications	0.2–6	3	15	80	70
Medium & Large Commercial Refrigeration	50–2,000	3	35	100	70
Transport Refrigeration	3–8	1	50	50	70
Industrial Refrigeration including Food Processing and Cold Storage	10–10,000	3	25	100	90
Chillers	10–2,000	1	15	100	95
Residential and Commercial A/C including Heat Pumps	0.5–100	1	10	80	80
Mobile Air Conditioning	0.5–1.5	0.5	20	50	50

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories

3.2. Method for Purchased Gases

For quantifying emissions from purchased gases, this method requires data that should be available from purchase records. The Method for Purchased Gases requires organizations to collect the following data:

- Type of gas purchased
- Amount of gas purchased
- Purpose for the gas

3.3. Material Balance Method

The recommended approach for organizations that maintain their own refrigerant-containing equipment is to calculate emissions based on the Material Balance Method. This method requires data that should be available from purchase and service records. The Material Balance Method requires organizations to collect the following data:

- Refrigerant inventory (in storage, not in operating equipment) at beginning of year
- Refrigerant inventory (in storage, not in operating equipment) at end of year
- 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 or disposed of
- Refrigerant returned to suppliers
- Refrigerant sent off-site for recycling or reclamation
- Refrigerant sent off-site for destruction
- Refrigerant capacity at beginning of year (in operating equipment, not storage)
- Refrigerant capacity at end of year (in operating equipment, not storage)

If beginning and ending capacity values are not known then the following information can be used:

- Refrigerant capacity of new equipment using this refrigerant
- Refrigerant capacity of equipment that is retrofitted to use this refrigerant
- Refrigerant capacity of retiring or sold equipment that used this refrigerant
- Refrigerant capacity of equipment that is retrofitted away from this refrigerant to a different refrigerant

Note: "Refrigerant capacity" refers to the full and proper charge of the equipment rather than to the actual charge, which may reflect leakage.

3.4. Simplified Material Balance Method

The Simplified Material Balance Method is the recommended approach for equipment users who have contractors service their equipment. If notified in advance of the need for this information, the contractor should be able to provide it. This method requires organizations to collect the following data:

- Refrigerant used to fill new equipment
- Refrigerant purchased to charge new equipment
- Refrigerant capacity of new equipment using this refrigerant
- Refrigerant purchased to service equipment
- Refrigerant capacity of retiring equipment
- Refrigerant recovered from retiring equipment

Note: "Refrigerant capacity" refers to the full and proper charge of the equipment rather than to the actual charge, which may reflect leakage.

Section 4: Completeness

In order for an organization's GHG inventory to be complete, it must include all emission sources within the organization's inventory boundaries. See Chapter 3 of the GHG Protocol for detailed guidance on setting organizational boundaries and Chapter 4 of the GHG Protocol for detailed guidance on setting operational boundaries of the inventory.

On an organizational level, an organization's inventory should include emissions from all applicable facilities or fleets of vehicles. Completeness of organization-wide emissions can be checked by comparing the list of sources included in the GHG emissions inventory with those included in other emission's inventories, environmental reporting, financial reporting, etc.

At the operational level, an organization should include all GHG emissions from the sources included in their GHG inventory. Possible GHG emission sources are stationary fuel combustion, combustion of fuels in mobile sources, purchases of electricity, and process or fugitive emissions. Organizations may refer to this guidance document for calculating fugitive GHG emissions from air conditioning and refrigeration equipment, as well as fire suppression equipment and industrial gases, and to the Center's Guidance documents for calculating emissions from other sources.

When calculating emissions from this equipment use, organizations should include all applicable sources of refrigerant emissions. If a third party is used for any component of refrigerant tracking, the third party should provide any necessary information. For the Screening Method, all pieces of equipment of all different types need to be accounted for. For the Material Balance Methods, all activities and different types of refrigerants or blends should be tracked.

As described in Chapter 1 of the GHG Protocol there is no materiality threshold set for reporting emissions. The materiality of a source can only be established after it has been assessed. This does not necessarily require a rigorous quantification of all sources, but at a minimum, an estimate based on available data should be developed for all sources.

Section 5: Uncertainty Assessment

There is uncertainty associated with all methods of calculating GHG emissions.

EPA does not recommend organizations quantify uncertainty as +/- % of emissions or in terms of data quality indicators. The effort spent to perform such analysis would be better spent pursuing high quality inventory data.

It is recommended that organizations identify the areas of uncertainty in their emissions calculations and make an attempt to use the most accurate data possible or conservative values when performing a screening analysis. As mentioned, the Screening Method for estimating emissions is highly uncertain. Factors vary between individual pieces of equipment and also over time. Even if the amount of refrigerant added to a particular piece of equipment has been tracked carefully, allowing the previous leak rate of that equipment to be established, that leak rate can change after the leak is repaired or as the equipment ages.

The major uncertainty introduced in the material balance approaches 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 material balance approaches provide a highly accurate estimate of emissions.

Section 6: Documentation

In order to ensure that emissions calculations are transparent and verifiable, the documentation sources listed in Table 4 should be maintained. These documentation sources should be collected to ensure the accuracy and transparency of the related emissions data, and should also be included in the organization's Inventory Management Plan (IMP).

Table 4: Documentation Sources

Data	Documentation Source
Inventory at Beginning and End of Year	Stock Inventory documentation
Purchases	Purchase receipts; delivery receipts; contract purchase
Nameplate Capacity of Equipment	Delivery receipts of equipment; records of physical inspection of nameplates; shipping or disposal records of equipment
Amounts Charged to Equipment	Repair records; repair invoices; daily reports
Amounts Recovered from Equipment	Repair records; repair invoices; daily reports; disposal records

Section 7: Inventory Quality Assurance and Quality Control (QA/QC)

Chapter 7 of the GHG Protocol provides general guidelines for implementing a QA/QC process for all emissions calculations. For the use of refrigeration and air conditioning equipment, the following items must be addressed:

- Care should be taken that releases are not double-counted (e.g., from reporting both refrigerant blend and individual blend component use).
- Verify that your inventory is complete. Because the GWPs of fluorinated compounds are so large (particularly when compared to carbon dioxide and methane), failure to account for even relatively small releases of fluorinated compounds can introduce significant errors. Also, tracking specific GHGs separately is important, because of the differing GWPs.