Greenhouse Gas Reporting – Quantification Methods
Feb. 12, 2009

Direct Emissions from Stationary Combustion

General Reporting Protocol

Chapter 12

Stationary Combustion

- **Direct emissions** of CO_2, CH_4 and N_2O from fuel combustion
  - in the production of electricity, steam, heat or power using equipment in a **fixed location**
  - Boilers, burners, turbines, furnaces and stationary applications of internal combustion engines

Data Quantification Tiers

- Tier A – most accurate and robust
- Tier B – alternative second best approach
- Tier C – least accurate but still acceptable approach

Data Quality Tiers for Stationary Combustion

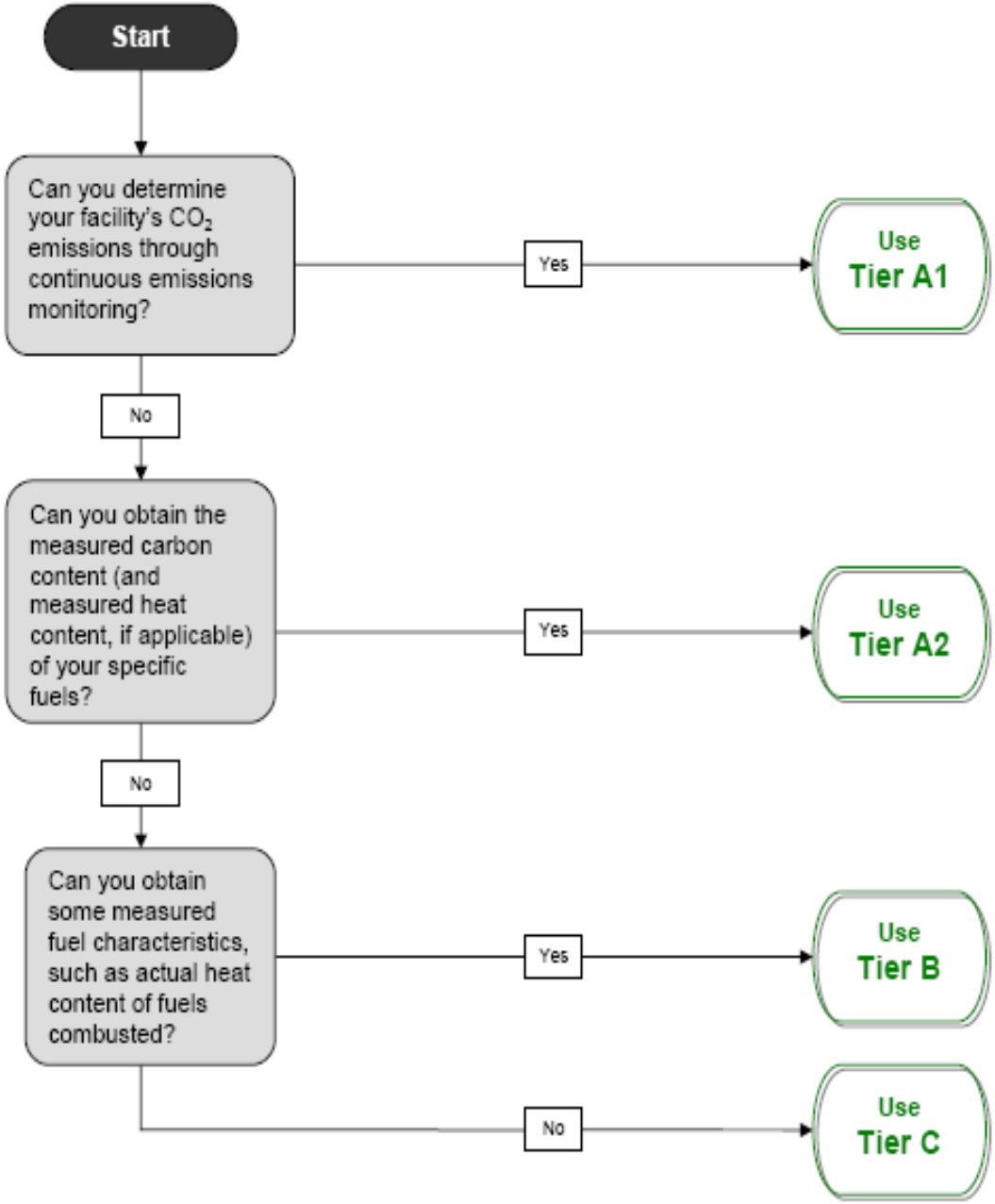
Direct CO_2 Emissions

Tier	Method	Emission Factors
A1	Direct Monitoring	Continuous emissions monitoring (CEMS) in accordance with 40 CFR Part 75
A2	Calculation Based on Fuel Use	• Measured carbon content of fuels (per unit mass or volume), or • Measured carbon content of fuels (per unit energy) and measured heat content of fuels
B	Calculation Based on Fuel Use	• Measured heat content of fuels and default carbon content (per unit energy), or • Measured carbon content (per unit energy) and default heat content of fuels
C	Calculation Based on Fuel Use	Default CO_2 emission factors by fuel type

Direct CH_4 and N_2O emissions

Tier	Method	Emission Factors
A	Direct Measurement	Continuous emissions monitoring or periodic direct measurements
B	Calculation Based on Fuel Use	Default emission factors by sector and technology type
C	Calculation Based on Fuel Use	Default emission factors by sector and fuel type

Selecting the data quality tier to determine **CO_2** emissions



Tier A1 for CO_2 Emissions -CEMS

- Power plants, large industrial facilities
- Continuous Emissions Monitoring Systems (CEMS)
- If reporting under 40 CFR 75 (acid rain program) continue requirements of installing, certifying, operating and maintaining CEMS

Tier A2 for CO_2 Emissions- Fuel Data

1. Determine annual fuel consumption
2. Determine CO_2 *emission factor* for each fuel
   - Need information on the *heat content* and the *carbon content* of each fuel
   - Fuel sampling & analysis or data from suppliers

Emission Factor = Heat Content x Carbon Content x % Oxidized x 44/ 12

(kg CO_2/gallon) = (Btu/gallon) x (kg C / Btu) x 1.0 x (CO_2/C)

Tier B For CO_2 Emissions -actual and default data

- Measured *heat content* with default *carbon content* or
- Measured *carbon content* with default *heat content*
- Combine specific data with default factors

  - TCR GRP Table 12.1 and 12.2

Example of CO_2 default factors from Table 12.1

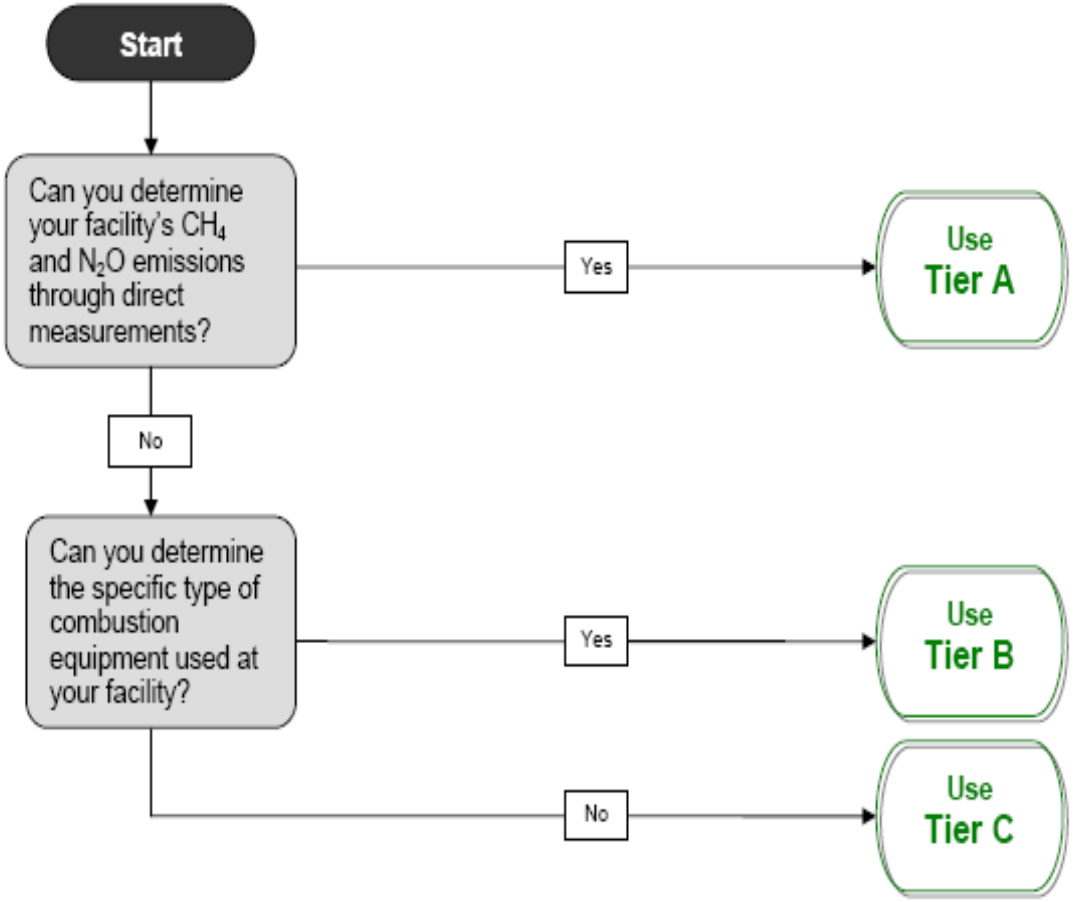
Fuel Type	Tier B Method			Tier C Method	
	Heat Content	Carbon Content (Per Unit Energy)	Fraction Oxidized	CO_2 Emission Factor (Per Unit Energy)	CO_2 Emission Factor (Per Unit Mass or Volume)
Coal and Coke	**MMBtu / Short ton**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / Short ton**
Anthracite Coal	25.09	28.26	1.00	103.62	2,599.83
Bituminous Coal	24.93	25.49	1.00	93.46	2,330.04
Sub-bituminous Coal	17.25	26.48	1.00	97.09	1,674.86
Lignite	14.21	26.30	1.00	96.43	1,370.32
Unspecified (Residential/ Commercial)	22.05	26.00	1.00	95.33	2,102.29
Unspecified (Industrial Coking)	26.27	25.56	1.00	93.72	2,462.12
Unspecified (Other Industrial)	22.05	25.63	1.00	93.98	2,072.19
Unspecified (Electric Utility)	19.95	25.76	1.00	94.45	1,884.53
Coke	24.80	31.00	1.00	113.67	2,818.93
Natural Gas (By Heat Content)	**Btu / Standard cubic foot**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / Standard cub. ft.**
975 to 1,000 Btu / Std cubic foot	975 – 1,000	14.73	1.00	54.01	Varies
1,000 to 1,025 Btu / Std cubic foot	1,000 – 1,025	14.43	1.00	52.91	Varies
1,025 to 1,050 Btu / Std cubic foot	1,025 – 1,050	14.47	1.00	53.06	Varies
1,050 to 1,075 Btu / Std cubic foot	1,050 – 1,075	14.58	1.00	53.46	Varies
1,075 to 1,100 Btu / Std cubic foot	1,075 – 1,100	14.65	1.00	53.72	Varies
Greater than 1,100 Btu / Std cubic foot	> 1,110	14.92	1.00	54.71	Varies
Unspecified (Weighted U.S. Average)	1,029	14.47	1.00	53.06	0.0546

Tier C for CO_2 emissions – Default EFs

- If neither *heat content* or *carbon content* can be measured then use default EFs
  - Table 12.1 and 12.2
  - For each fuel
    - Fuel use x EF; then covert kg to metric tons; then sum

Fuel A CO_2 Emissions (metric tons) = Fuel Consumed x Emission Factor ÷ 1,000 (gallons) (kg CO_2/gallon) (kg/metric ton)
Fuel B CO_2 Emissions (metric tons) = Fuel Consumed x Emission Factor ÷ 1,000 (gallons) (kg CO_2/gallon) (kg/metric ton)
Total CO_2 Emissions (metric tons) = CO_2 from Fuel A + CO_2 from Fuel B + … (metric tons) (metric tons) (metric tons)

Selecting the data quality tier to determine **CH_4** and **N_2O** emissions



Tier A & B for CH_4 and N_20 EFs

- Tier A – direct monitoring
- Tier B – default EFs by sector & technology
  - Table 12.5: default CH_4 and N_20 EFs by Technology for the **Electricity Generation sector**
  - Table 12.6: default CH_4 and N_20 EFs for **Kilns, Ovens and Dryers**
  - Table 12.7: default CH_4 and N_20 EFs by technology type for the **Industrial Sector**
  - Table 12.8: default CH_4 and N_20 EFs by technology type for the **Commercial Sector**

Tier C for CH_4 and N_2O Emissions

- Tier C – default EFs by Sector and Fuel

  CH_4

Fuel/Technology Type A **CH_4 Emissions** = Fuel Use × Emission Factor ÷ 1,000,000 (metric tons) (MMBtu) (g CH_4/MMBtu) (g/metric ton)
Fuel/Technology Type B **CH_4 Emissions** = Fuel Use × Emission Factor ÷ 1,000,000 (metric tons) (MMBtu) (g CH_4/MMBtu) (g/metric ton)
Total CH_4 Emissions (metric tons) = CH_4 from Type A + CH_4 from Type B + … (metric tons) (metric tons) (metric tons)

- N_2O

Fuel/Technology Type A **N_2O Emissions** = Fuel Use × Emission Factor ÷ 1,000,000 (metric tons) (MMBtu) (g N_2O/MMBtu) (g/metric ton)
Fuel/Technology Type B **N_2O Emissions** = Fuel Use × Emission Factor ÷ 1,000,000 (metric tons) (MMBtu) (g N_2O/MMBtu) (g/metric ton)
Total N_2O Emissions (metric tons) = N_2O from Type A + N_2O from Type B + … (metric tons) (metric tons) (metric tons)

Fuel Type / End-Use Sector	CH_4 (g/MMBtu)	N_2O (g/MMBtu)
Coal		
Residential	316	1.6
Commercial	11	1.6
Industrial	11	1.6
Electric Power	1	1.6
Petroleum Products		
Residential	11	0.6
Commercial	11	0.6
Industrial	3	0.6
Electric Power	3	0.6
Natural Gas		
Residential	5	0.1
Commercial	5	0.1
Industrial	1	0.1
Electric Power	1	0.1
Wood		
Residential	316	4.2
Commercial	316	4.2
Industrial	32	4.2
Electric Power	32	4.2
Pulping Liquors		
Industrial	2.5	2.0

Source: EPA Climate Leaders, Stationary Combustion Guidance (2007), Table A-1, based on U.S. EPA, *Inventory of Greenhouse Gas Emissions and Sinks: 1990-2005* (2007), Annex 3.1.

Convert to CO_2e Using Appropriate GWP

Equation 12j	Converting to CO_2-Equivalent and Determining Total Emissions
CO_2 Emissions (metric tons CO_2e)	= CO_2 Emissions (metric tons) x 1 (GWP)
CH_4 Emissions (metric tons CO_2e)	= CH_4 Emissions (metric tons) x 21 (GWP)
N_2O Emissions (metric tons CO_2e)	= N_2O Emissions (metric tons) x 310 (GWP)
Total Emissions (metric tons CO_2e)	= $CO_2 + CH_4 + N_2O$ (metric tons CO_2e)

- See example page 71
- F&M mfg company
- Tier A2 – estimating CO_2
- Tier C for estimating CH_4 and N_2O

Direct Emissions from Mobile Combustion

General Reporting Protocol

Chapter 13

Mobile Combustion

Direct emissions of CO_2, CH_4 and N_2O from mobile equipment combustion

- On-road motor vehicles - including: passenger cars, SUVs, vans, buses, trucks, etc
- Non-road motor vehicles - including: trains, marine vessels, airplanes, construction equipment, farming equipment, forklifts, etc

Thresholds – On-Road Fleet and Other Sources

Stationary and Non-Road Mobile Sources

≥ 10,000 MT CO_2e
= report all emissions including on-road

< 10,000 MT CO_2e
= do not report stationary and non-road mobile sources

On-Road Fleet
≥ 2,500 MT CO_2e
= report on-road

Mobile Combustion Tiers

Data Quality Tiers: Direct CO_2 Emissions From Mobile Combustion		
Tier	**Activity Data**	**Emission Factors**
A1	Fuel use	• Measured carbon content (per unit mass) and measured density of fuels, or • Measured carbon content (per unit energy) and measured heat content of fuels
A2	Fuel use	• Measured heat content of fuels and default carbon content (per unit energy), or • Measured carbon content (per unit energy) and default heat content of fuels
B	Fuel use	Default CO_2 emission factors by fuel type
C	Fuel use estimated using vehicle miles traveled and vehicle fuel economy	Default CO_2 emission factors by fuel type

Data Quality Tiers: Direct CH_4 & N_2O Emissions From Mobile Combustion (Non-Highway Vehicles)		
Tier	**Activity Data**	**Emission Factors**
A	Fuel use	Default emission factors by vehicle type and fuel type
B	Fuel use estimated using vehicle miles traveled and vehicle fuel economy	Default emission factors by vehicle type and fuel type

Data Quality Tiers: Direct CH_4 & N_2O Emissions From Mobile Combustion (Highway Vehicles)		
Tier	**Activity Data**	**Emission Factors**
A	Miles traveled by vehicle type	Default emission factors by vehicle type based on vehicle technology
B	Miles traveled by vehicle type	Default emission factors by vehicle type based on model year
C	Distance estimated using fuel use and vehicle fuel economy	Default emission factors by vehicle type based on vehicle technology or model year

Tier A for CO_2 Emissions – Measured Fuel Properties

- Measure fuel use by type

- Tier A1:
  - Measured carbon content (per unit mass) and fuel density of fuels, or
  - Measured carbon content (per unit energy) and heat content of fuels
- Tier A2:
  - Measured heat content and default carbon content (per unit energy), or
  - Measured carbon content (per unit energy) and default heat content of fuels

Tier B for CO_2 Emissions – Default Fuel Emission Factors

- Measure fuel use by type
- Default CO_2 emission factors by fuel type
- Method used in online calculator
  - http://www.ecy.wa.gov/programs/air/globalwarm_RegHaze/GHGonroadworkshops.htm

TCR Tier B CO_2 Emission Factors

Table 13.1 U.S. Default CO_2 Emission Factors for Transport Fuels

Fuel Type	Tier A2 Method			Tier B/C Method
	Carbon Content (Per Unit Energy)	Heat Content	Fraction Oxidized	CO_2 Emission Factor (Per Unit Volume)
Fuels Measured in Gallons	**kg C / MMBtu**	**MMBtu / barrel**		**kg CO_2 / gallon**
Motor Gasoline	19.33	5.218	1.00	8.81
Diesel Fuel No.1 and 2	19.95	5.825	1.00	10.15
Aviation Gasoline	18.87	5.048	1.00	8.32
Jet Fuel (Jet A or A-1)	19.33	5.670	1.00	9.57
Kerosene	19.72	5.670	1.00	9.76
Residual Fuel Oil (#5,6)	21.49	6.287	1.00	11.80
Crude Oil	20.33	5.80	1.00	10.29
Biodiesel (B100)*	NA	NA	1.00	9.46
Ethanol (E100)*	17.99	3.539	1.00	5.56
Methanol**	NA	NA	1.00	4.10
Liquefied Natural Gas (LNG)*	NA	NA	1.00	4.46
Liquefied Petroleum Gas (LPG)*	17.23	3.849	1.00	5.79
Propane	17.20	3.824	1.00	5.74
Ethane	16.25	2.916	1.00	4.14
Isobutane	17.75	4.162	1.00	6.45
n-Butane	17.72	4.328	1.00	6.70
Fuels Measured in Standard Cubic Feet	**kg C / MMBtu**	**Btu / Standard cubic foot**		**kg CO_2 / Standard cubic foot**
Compressed Natural Gas (CNG)*	14.47	1,027	1.00	0.054

Source: U.S. EPA, *Inventory of Greenhouse Gas Emissions and Sinks: 1990-2005* (2007), Annex 2.1, Tables A-31, A-34, A-36, A-39, except those marked * (from EPA Climate Leaders, Mobile Combustion Guidance, 2007) and ** (from California Climate Action Registry *General Reporting Protocol* Version 2.2, 2007, Table C.3). A fraction oxidized value of 1.00 is from the IPCC, *Guidelines for National Greenhouse Gas Inventories* (2006). Note: Default CO_2 emission factors are calculated using Equation 12d: Heat Content × Carbon Content × Fraction Oxidized × 44/12 × Conversion Factor. Heat content factors are based on higher heating values (HHV). NA = data not available.

Tier C for CO_2 Emissions – Mileage and Default Fuel Emission Factors

- Measure mileage by fuel and vehicle type
  - Use to estimate fuel use based on fuel economy
  - Measured or reference mpg, but must be vehicle specific
- Default CO_2 emission factors by fuel type
  - Same factors as Tier B

Tier A for On-Road CH_4 and N_2O Emissions – Miles Traveled by Control Technology

- Measure mileage by fuel type aggregated by vehicle emissions control technology

- Default emission factors by vehicle type based on emissions control technology
  - Mileage based factors
  - Table 13.3
  - Convert to CO_2e

Tier B for On-Road CH_4 and N_2O Emissions – Miles Traveled by Model Year

- Measure mileage by fuel type aggregated by vehicle model year

- Default emission factors by vehicle type based on model year
  - Mileage based factors
  - Table 13.4
  - Convert to CO_2e

Tier C for On-Road CH_4 and N_2O Emissions – Fuel Use by Vehicle Type

- Measure fuel use by fuel and vehicle type
  - Use to estimate mileage based on fuel economy
  - Measured or reference mpg, but must be vehicle specific

- Default emission factors by vehicle type based on emissions control technology or model year
  - Mileage based factors
  - Tables 13.3 and 13.4
  - Convert to CO_2e

Simplified Method for On-Road CH_4 and N_2O Emissions – Fuel Use and Default Emission Factors

- Not a tiered method – counts towards simplified estimation methods threshold
  - CH_4 and N_2O Emissions small enough to qualify in almost all cases
  - This method adapted from 2006 IPCC Guidelines for National Greenhouse Gas Inventories Vol.2 Table 2.2
  - Can devise alternate methods – see GRP Chapter 11 for details

- Measure fuel use by type
  - No need to convert to mpg

- Default emission factors by fuel type
  - http://www.ecy.wa.gov/programs/air/globalwarm_RegHaze/GHGonroadworkshops.htm
  - Convert to CO_2e

Tier A for Non-Road CH_4 and N_2O Emissions – Fuel Use by Vehicle Type

- Measure fuel use by type
  - No need to convert to mileage
- Default emission factors by vehicle type
  - Table 13.6
  - Convert to CO_2e

Tier B for Non-Road CH_4 and N_2O Emissions – Mileage by Vehicle Type

- Measure mileage by fuel and vehicle type
  - Use to estimate fuel use based on fuel economy
  - Measured or reference mpg, but must be vehicle specific
- Default emission factors by vehicle type
  - Same factors as Tier A
  - Table 13.6
  - Convert to CO_2e

Separating In-State Emissions

- Only report emissions occurring in Washington – do not report emissions from out of state
- On-road fleets: three methods to choose from
- Tiered system - start with Tier A and if data not available proceed to Tiers B and C
- Can round up emissions for small amounts if too expensive to track
  - Ecology reports 100% of emissions as instate
- Method must be used consistently throughout organization and over time

In-State Emissions Tier A – Prorated Mileage

- Determine percentage of miles traveled inside Washington out of total miles traveled by organization
  - By vehicle and fuel type
- Report emissions from instate miles or multiply total raw data (fuel use, HFC sources, etc) by Washington percentage and use to calculate emissions

- Example: Interstate trucking company with 50 trucks (all with 1 AC unit) travels 47% of their miles in Washington and consumes 5,000,000 total gallons of diesel
  - 5,000,000 gallons x 0.47 = 2,350,000 reportable gallons
  - 50 AC units x 0.47 = 23.5 reportable AC units

In-State Emissions Tier B – Fuel Purchase Location

- Determine fuel purchased inside of Washington by organization
  - By vehicle and fuel type
- Report emissions from instate fuel purchases or multiply total raw data (fuel use, HFC sources, etc) by Washington percentage and use to calculate emissions

- Example: Company with 500 vehicles (all with 1 AC unit) purchases 300,000 gallons of gasoline in Washington and 75,000 gallons of gasoline in Oregon
  - 300,000 reportable gallons
  - 500 AC units x (300,000/375,000) = 400 reportable AC units

In-State Emissions Tier C – Vehicle Base Location

- Determine emissions for vehicles based inside of Washington
  - By vehicle and fuel type
- Report emissions from vehicles based instate or multiply total raw data (fuel use, HFC sources, etc) by Washington percentage and use to calculate emissions

- Example: Company with a rental fleet based in Washington with 1,000 vehicles (all with 1 AC unit) travels 10,000,000 miles a year and a second fleet based in Idaho with 200 vehicles traveling 2,000,000 miles
  - 10,000,000 reportable miles
  - 1,000 reportable AC units

Non-Road Separating In-State Emissions

- Non-road mobile methods still in development, but likely similar to on-road sources
- Emissions from intrastate aircraft to be reported in 2013 (2012 emissions) and interstate emissions deferred
  - All other mobile source emissions to be reported starting in 2010 (2009 emissions) for both intrastate and interstate

Indirect Emissions from Electricity Use

General Reporting Protocol

Chapter 14

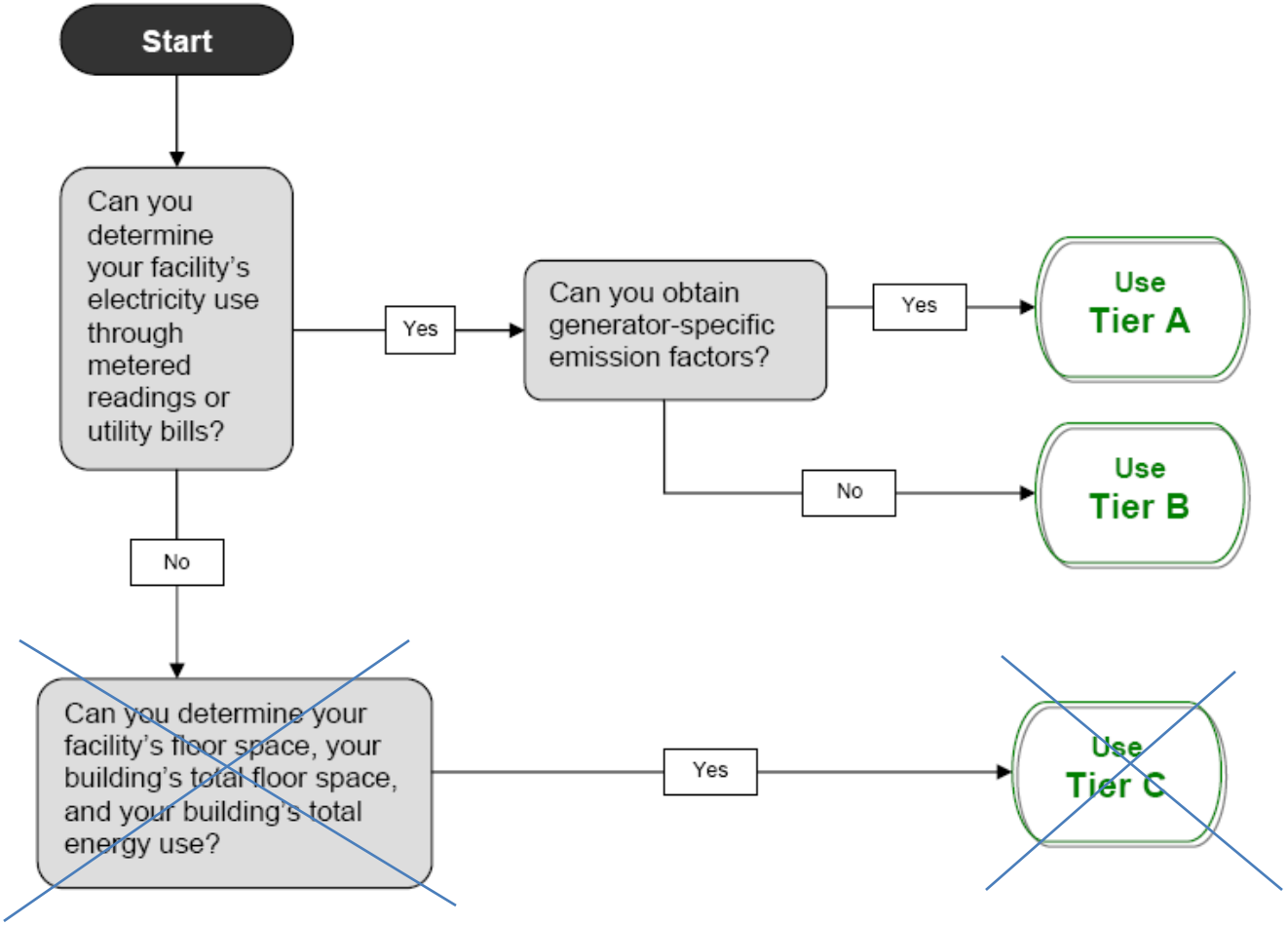
Data Quantification Tiers

- Tier A – most accurate and robust
- Tier B – alternative second best approach

Data Quality Tiers for Indirect Emissions

Data Quality Tiers: Indirect CO_2, CH_4 and N_2O Emissions From Electricity		
Tier	**Activity Data**	**Emission Factors**
A	Known electricity use (Metered readings or utility bills)	Generator-specific emission factors
B	Known electricity use (Metered readings or utility bills)	eGRID power pool-specific factors
C	~~Estimated electricity use (Area method)~~	~~Generator-specific or eGRID power pool-specific factors~~

Selecting Data Quality Tier



Emission Factors

- Tier A –
  - generator specific EF
- Tier B –
  - region specific EF
  - eGrid 2006 subregion
  - NWPP WECC, Map # 21

Figure 14.2 Map of U.S. eGRID Subregions, 2004

(lbs CO_2/MWh)	(lbs CH_4/MWh)	(lbs N_2O / MWh)
921.10	0.022	0.014

Calculating Indirect Emissions from Electricity Use

Equation 14b	Calculating Indirect Emissions from Electricity Use
CO_2 Emissions (metric tons) = Electricity Use (MWh) × Emission Factor (lbs CO_2/MWh) ÷ 2,204.62 (lbs/metric ton) **CH_4 Emissions** (metric tons) = Electricity Use (MWh) × Emission Factor (lbs CH_4/MWh) ÷ 2,204.62 (lbs/metric ton)	
N_2O Emissions (metric tons) = Electricity Use (MWh) × Emission Factor (lbs N_2O/MWh) ÷ 2,204.62 (lbs/metric ton)	

Equation 14c	Converting to CO_2-Equivalent and Determining Total Emissions
CO_2 Emissions (metric tons CO_2e) = CO_2 Emissions (metric tons) × 1 (GWP)	
CH_4 Emissions (metric tons CO_2e) = CH_4 Emissions (metric tons) × 21 (GWP)	
N_2O Emissions (metric tons CO_2e) = N_2O Emissions (metric tons) × 310 (GWP)	
Total Emissions (metric tons CO_2e) = CO_2 + CH_4 + N_2O (metric tons CO_2e)	

Indirect Emissions from Imported Steam, District Heating, Cooling, and Electricity from a Combined Heat and Power Plant

General Reporting Protocol

Chapter 15

Covered Activities

- Electricity or heat purchased from a combined heat and power facility
- Steam imported for heating and process uses from central steam plant
- District cooling system emissions

Data Quality Tiers – Combined Heat & Power

Data Quality Tiers: Indirect Emissions from Combined Heat and Power (CHP)	
Tier	Method
A	CHP plant emissions calculated using a Tier A method from Chapter 12, Stationary Combustion
B	CHP plant emissions calculated using a Tier B method from Chapter 12
C	CHP plant emissions calculated using a Tier C method from Chapter 12

Direct Emissions from Combustion

- Use direct combustion methods from Chapt 12, Direct Emissions from Stationary Combustion, to determine GHG emissions due to use of fuels.
- Use direct combustion methods from Chapt. 13, Direct Emissions from Mobile Sources, to determine emissions from mobile sources.

Considerations

The process for estimating your indirect emissions from heat and power produced at a CHP plant involve:

1. Obtain total emissions, power, and heat generation information from the CHP facility
2. Determine emissions attributable to net heat production and electricity production
3. Calculate emissions attributable to your portion of the total heat and electricity produced
4. Convert emissions to units of carbon dioxide equivalents and determine total emissions

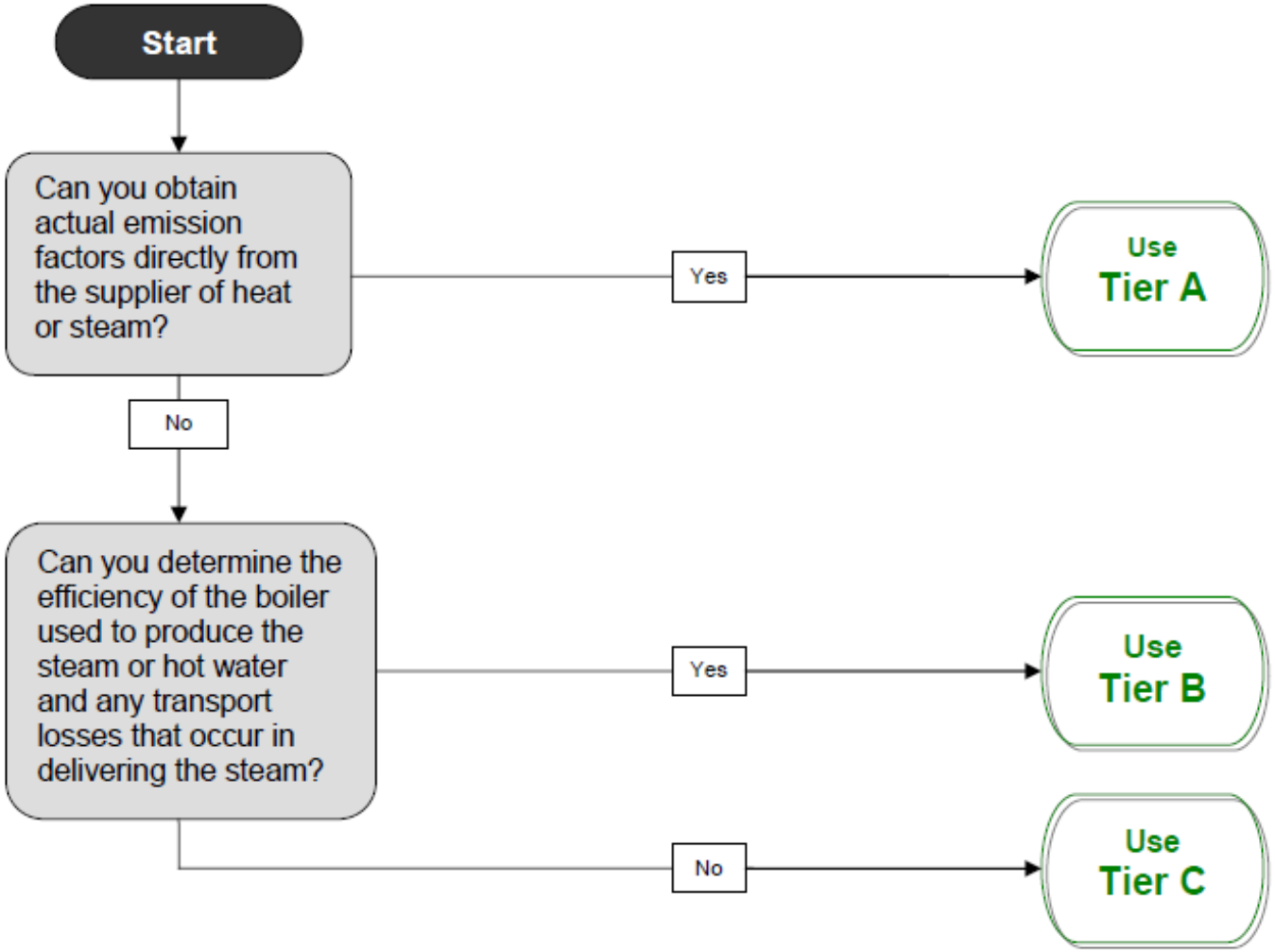
Equation 15b	Calculating Indirect Emissions Attributable To Electricity Consumption
Indirect Emissions Attributable to Electricity Consumption (*metric tons*) = Total CHP Emissions Attributable to Electricity Production (*metric tons*) × (Your Electricity Consumption (*kWh*) ÷ Total CHP Electricity Production (*kWh*))	

Equation 15c	Calculating Indirect Emissions Attributable To Heat (or Steam) Consumption
Indirect Emissions Attributable to Heat Consumption (*metric tons*) = Total CHP Emissions Attributable to Heat Production (*metric tons*) × (Your Heat Consumption (*MMBtu*) ÷ CHP Net Heat Production (*MMBtu*))	

Data Quality Tiers – Imported Steam or Heat

Data Quality Tiers: Indirect Emissions from Imported Steam or Heat	
Tier	Method
A	Measured emission factors obtained directly from the supplier
B	Efficiency approach using source-specific efficiency factor
C	Efficiency approach using default efficiency factor

Indirect Emissions - Imported Steam or Heat



Considerations

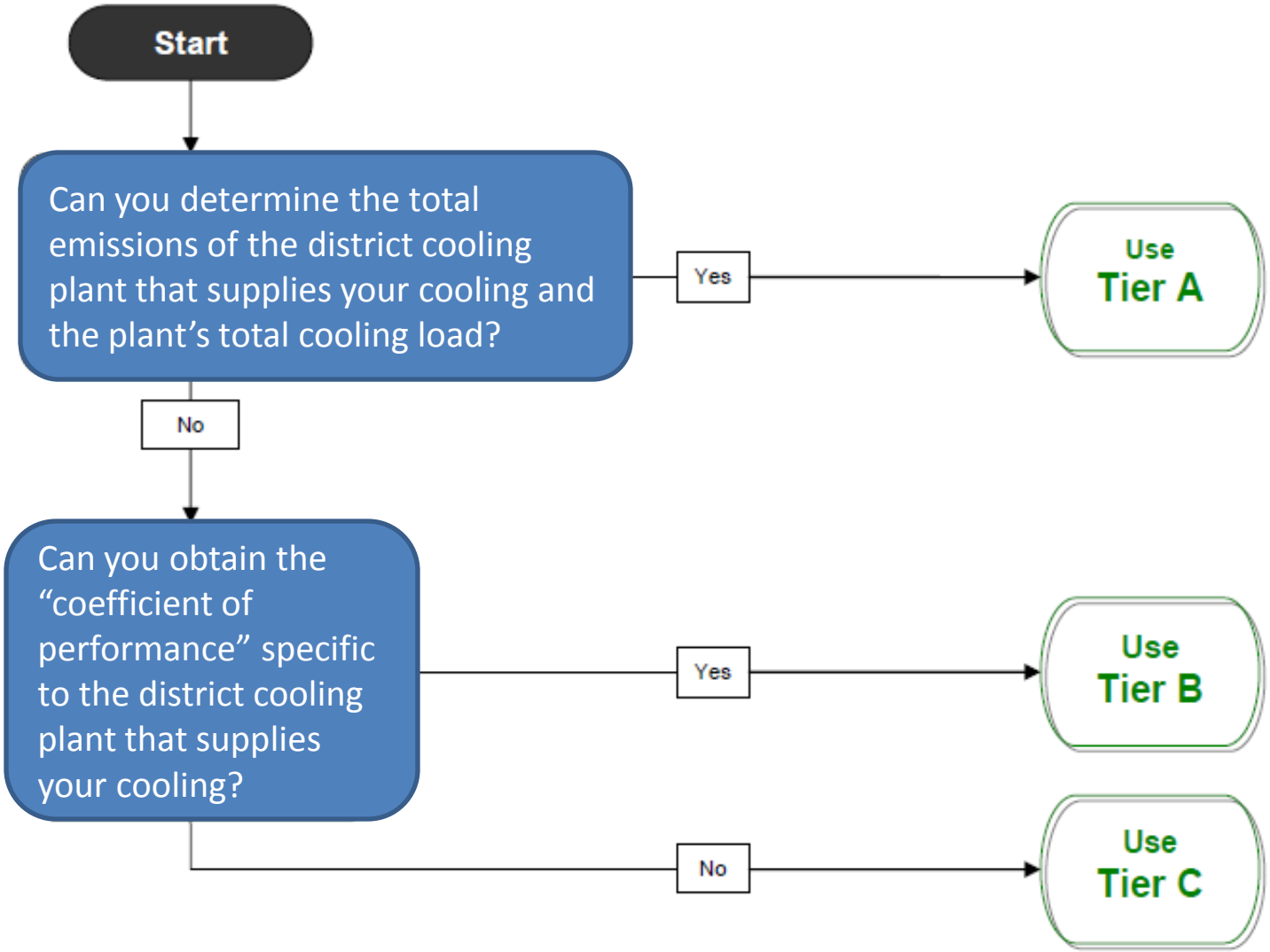
To estimate your facility's GHG emissions from imported steam or district heating:

1. Determine energy you obtained from steam or district heating;
2. Determine appropriate emission factors for the source of the steam or district heating;
3. Calculate emissions attributable to your imported steam or district heating; and
4. Convert emissions to units of carbon dioxide equivalent, and determine total emissions

Data Quality Tiers – District Cooling

Data Quality Tiers: Indirect Emissions from District Cooling	
Tier	Method
A	Detailed approach
B	Simplified approach with source specific coefficient of performance
C	Simplified approach with default coefficient of performance

Indirect Emissions – District Cooling



Considerations

Your indirect emissions from district cooling represent your share of the total cooling demand from the cooling plant, multiplied by the total GHG emissions generated by that plant.

1. Determine your total cooling use by summing the total cooling from your monthly cooling bills.
2. Once you have determined your total cooling, you can use either the detailed approach (Tier A) or simplified approach (Tier B or C) to estimate your GHG emissions from district cooling.

See Chapter 15, Section 15.3 for details

Direct Fugitive Emissions from the Use of Refrigeration and Air Conditioning Equipment

General Reporting Protocol

Chapter 16

Fugitive Emissions from Refrigeration and Air Conditioning

- Applies to refrigeration and air conditioning equipment, including: household, commercial, industrial, and motor vehicle refrigeration and air conditioning systems
- High GWP gases - hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs)
- Method can also be adapted for other coolants such as CO_2
- Calculations performed separately for each refrigerant type

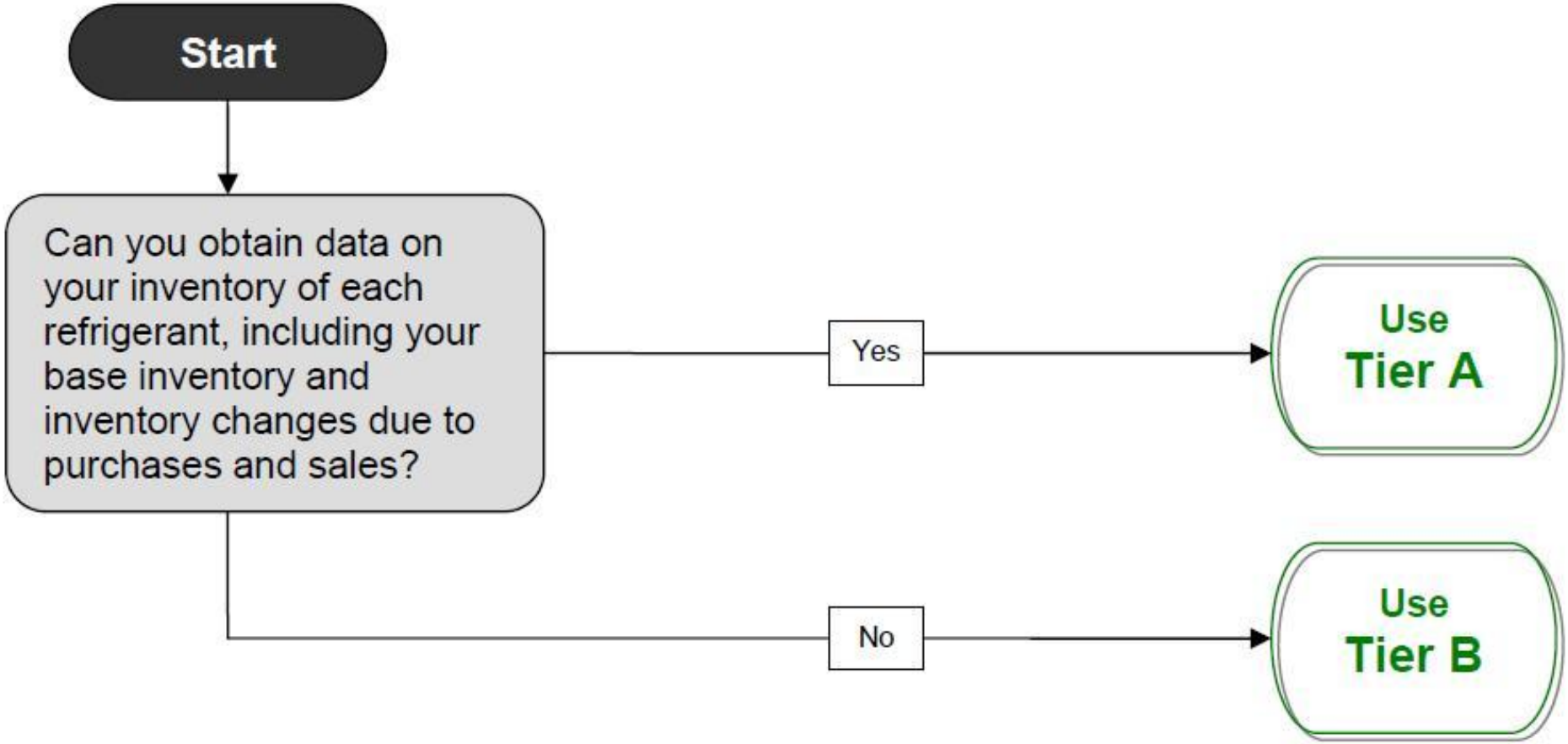
Fugitive Refrigeration and Air Conditioning Tiers

Data Quality Tiers: Direct Fugitive Emissions From the Use of Refrigeration and Air Conditioning Equipment	
Tier	**Method**
A	Mass balance method
B	Simplified mass balance method

GRP also contains untiered “Screening Method”

- Simplified method for stationary sources
- Considered tiered method for on-road mobile sources

Figure 16.1 - Tier Selection



- Stationary sources must use diagram to determine calculation method
- Fleets of on-road motor vehicles may select any tier, including the Screening Method

Tier A – Mass Balance

1. Determine the base inventory for each refrigerant
2. Calculate changes to the base inventory for each refrigerant
3. Calculate annual emissions of each type of refrigerant, convert to units of CO_2e, and total

Equation 16a	Calculating Emissions of Each Type of HFC and PFC Using the Mass Balance Method

Total Annual Emissions (metric tons of HFC or PFC) =
(A - B + C - D - E) ÷ 1,000
(kg) (kg) (kg) (kg) (kg) (kg/metric tons)

Table 16.1 Base Inventory and Inventory Changes

	Inventory	Amount (kg)
Base Inventory		
A	Refrigerant in inventory (storage) at the beginning of the year	
B	Refrigerant in inventory (storage) at the end of the year	
Additions to Inventory		
1	Purchases of refrigerant (including refrigerant in new equipment)	
2	Refrigerant returned to the site after off-site recycling	
→ C	Total Additions (1+2)	
Subtractions from Inventory		
3	Returns to supplier	
4	HFCs taken from storage and/or equipment and disposed of	
5	HFCs taken from storage and/or equipment and sent off-site for recycling or reclamation	
→ D	Total Subtractions (3+4+5)	
Net Increase in Full Charge/Nameplate Capacity		
6	Total full charge of new equipment	
7	Total full charge of retiring equipment	
→ E	Change to nameplate capacity (6-7)	

Tier B – Simplified Mass Balance

1. Determine the types and quantities of refrigerants used
2. Calculate annual emissions of each type of refrigerant
3. Convert to units of CO_2e and total

Equation 16d	Calculating Emissions of Each Type of Refrigerant

Total Annual Emissions (metric tons) =
$(P_N - C_N + P_S + C_D - R_D) \div 1{,}000$
(kg) (kg) (kg) (kg) (kg) (kg/metric tons)

Where:
P_N = purchases of refrigerant used to charge new equipment *
C_N = total full charge of the new equipment *
P_S = quantity of refrigerant used to service equipment
C_D = total full charge of retiring equipment
R_D = refrigerant recovered from retiring equipment

* Omitted if the equipment has been pre-charged by the manufacturer

Screening Method

Equation 16e	Estimating Emissions of Each Type of Refrigerant using the Screening Method

For each type of refrigerant:

Total Annual Emissions = [$(C_N \times k) + (C \times x \times T) + (C_D \times y \times (1 - z))$ **]** ÷ 1,000

(metric tons) (kg) (%) (kg) (%) (years) (kg) (%) (%) (kg/metric ton)

Where:

C_N = quantity of refrigerant charged into the new equipment [1]

C = total full charge (capacity) of the equipment

T = time in years equipment was in use (e.g., 0.5 if used only during half the year and then disposed)

C_D = total full charge (capacity) of equipment being disposed of [2]

k = installation emission factor [1]

x = operating emission factor

y = refrigerant remaining at disposal [2]

z = recovery efficiency [2]

[1] Omitted if no equipment was installed during the reporting year or the installed equipment was pre-charged by the manufacturer

[2] Omitted if no equipment was disposed of during the reporting year

- Use Table 16.3 for emission factors
- If charge capacity unknown, use upper bound of listed range
- All changes from default emission factors must be documented

Converting to CO_2e

Table 16.2 – GWPs of Refrigerant Blends

Refrigerant Blend	Global Warming Potential	Refrigerant Blend	Global Warming Potential
R-401A	18	R-413A	1,774
R-401B	15	R-414A	0
R-401C	21	R-414B	0
R-402A	1,680	R-415A	25
R-402B	1,064	R-415B	105
R-403A	1,400	R-416A	767
R-403B	2,730	R-417A	1,955
R-404A	3,260	R-418A	4
R-406A	0	R-419A	2,403
R-407A	1,770	R-420A	1,144
R-407B	2,285	R-500	37
R-407C	1,526	R-501	0
R-407D	1,428	R-502	0
R-407E	1,363	R-503	4,692
R-408A	1,944	R-504	313
R-409A	0	R-505	0
R-409B	0	R-506	0
R-410A	1,725	R-507 or R-507A	3,300
R-410B	1,833	R-508A	10,175
R-411A	15	R-508B	10,350
R-411B	4	R-509 or R-509A	3,920
R-412A	350	Source: ASHRAE Standard 34	

- Multiply MT of each refrigerant by GWP
- GWP from rule text, Table B.1, or Table 16.2

Direct Emissions from Sector-Specific Sources

General Reporting Protocol

Appendix E

Process Emission Sources

- Adipic Acid (N_2O)
- E.2 Aluminum (CO_2, PFCs)
- E.3 Ammonia (CO_2)
- E.4 Cement (CO_2)
- E.5 Electricity Transmission and Distribution (SF_6)
- HCFC-22 Production (HFC-23)
- E.7 Iron and Steel (CO_2)
- E.8 Lime (CO_2)
- E.9 Nitric Acid (N_2O)
- E.10 Pulp and Paper (CO_2)
- Refrigeration and A/C Equipment Manufacture (PFCs, HFCs)
- E.11 Semiconductors (PFCs, SF_6)

Direct Emissions from Combustion

- Use direct combustion methods from Chapt 12, Direct Emissions from Stationary Combustion, to determine GHG emissions due to use of fuels.
- Use direct combustion methods from Chapt. 13, Direct Emissions from Mobile Sources, to determine emissions from mobile sources.

Data Quality Tiers for Process Emissions

Data Quality Tiers: Direct Process Emissions		
Tier	Activity Data	Emission Factors
A-1	Continuous or Periodic Direct Emission Monitoring	N/A
A	Process Specific Mass Balance	Plant specific emission factors
B	Process Specific Mass Balance	Default or Industry typical emission factors
C	Not applicable for most process emissions sources	

Cement Plants, Carbonate Input Method

Tier	Method	Emission Factors
A	Carbonate Input Method	Plant-specific factors
B	Carbonate Input Method	Default factors: • Fi = 1.00 • Fd = 1.00 • Cd = the calcium carbonate ratio in the raw material feed to the kiln • EFd = the emission factor for calcium carbonate • CO2 emissions from non-carbonate carbon in the non-fuel raw materials can be ignored (set Mk • Xk • EFk = 0) if the heat contribution from the non-carbonate carbon is < 5% of total heat (from fuels).

This method also applicable to Lime Plants

Cement Plants, Clinker Method

Tier	Method	Emission Factors
Process CO_2 emissions from Clinker Calcination		
A	Clinker Method	Plant-specific clinker emission factor: • Measured CaO- and MgO content of a plant's clinker • Measured non-carbonate fractions of CaO and MgO
B	Clinker Method	Default clinker emission factor: • Default clinker EF = 525 kg CO_2/ metric tons clinker
Process CO_2 emissions from Discarded Cement Kiln Dust		
A1	Direct Measurement	n/a
A2	Mass Balance	Plant-specific CKD emission factor: • Plant-specific clinker emission factor • Plant-specific CKD calcination rate
B	Mass Balance	Default CKD emission factor: • CKD calcination rate (d) = 1 • Default clinker EF = 525 kg CO_2/ metric tons clinker
Process CO_2 emissions from Organic Carbon in Raw Meal		
A	Mass Balance	Measured organic carbon content
B	Mass Balance	Default organic carbon content = 0.2%

E.10 Pulp and Paper

- Tier A for the whole plant would be based on use of CEMS or *Calculation Tools for Estimating Greenhouse Gas Emissions from Pulp and Paper Mills, Version 1.1, July 8, 2005 (ICFPA)*

Direct Process CO_2 Emissions from Make-Up Carbonates Used in the Pulp Mill

Tier	Method	Emission Factors
A	Mass Balance	Default stoichiometric emission factors

Direct Process CO_2 Emissions from Limestone or Dolomite Used in Flue Gas Desulfurization Systems

Tier	Method	Emission Factors
A	Mass Balance	Default stoichiometric emission factors

E.12 Semiconductors

Direct Process PFC and SF_6 Emissions from Plasma Etching and Chemical Vapor Deposition (CVD)

Tier	Method	Emission Factors
A	Mass Balance Using Process-Specific Parameters	Plant-specific factors: • For each parameter used in Equations 6.7 – 6.11 for each individual process • 'p' in the equations is a specific 'process' (e.g., silicon nitride etching or plasma enhanced chemical vapor deposition (PECVD) tool chamber cleaning), not a 'process type' (e.g. etching vs. CVD chamber cleaning)
B	Mass Balance Using Process Type-Specific Parameters	Plant-specific factors: • For each parameter used in Equations 6.7 – 6.11 for each process type • 'p' in the equations is a 'process type' (etching vs. CVD chamber cleaning)
C	Mass Balance Using Process Type-Specific Parameters	Default factors: Industry-wide default values used for any or all of the following parameters: • h = 0.10 • Ui,p (IPCC Table 6.3, Tier 2b) • BCF4,i,p, BC2F6,i,p, BC3F8,i,p (IPCC Table 6.3, Tier 2b) • di,p, dCF4,p, dC2F6,p, dCHF3,p and dC3F8,p (IPCC Table 6.6) • ai,p = 0 (unless emission control technologies are installed)