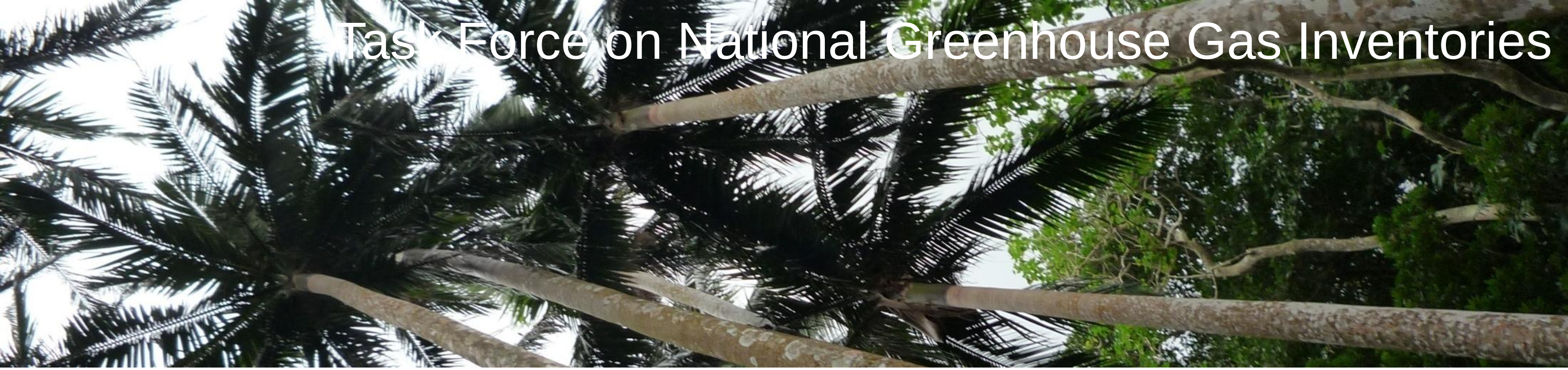

Industrial Processes and Product Use Sector

Regional African Workshops on REDD+ National Forest Monitoring Systems and Greenhouse Gas National Inventory Systems

25-27 February 2014

Livingstone, Zambia

Kiyoto Tanabe
Technical Support Unit, IPCC TFI

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Outline

- Overview
- What gases?
- What sources?
- What features?
- Important for non-Annex I Parties?
- Methods for each category

Emissions from Industrial Processes

- Emissions from manufacturing processes that chemically or physically transform materials: e.g.,
  - CO_2 released from calcination of limestone ($CaCO_3$) in cement production
  - CO_2 generated from use of coke as a reducing agent in production of iron
  - HFC-23 generated as by-product from production of HCFC-22
- Emissions from fuel combustion in industrial activities are NOT included.
  - ➔ Calculated and reported in Energy Sector

Emissions from Product Use

- GHGs are used in products and eventually released to the atmosphere:
  e.g.,
  - HFCs and PFCs: Used as substitutes for ozone depleting substances (e.g., refrigerants)
  - SF_6: Used in electrical equipment for electrical insulation and current interruption
  - N_2O: Used as anesthesia
  - NMVOCs: Used as solvents

Reporting Categories

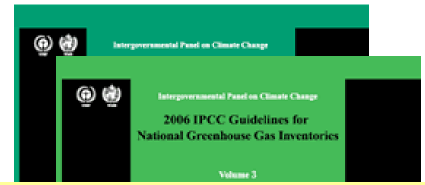
1996 Guidelines + GPG2000

Sector 2: Industrial Processes

- 2A: Mineral Products
- 2B: Chemical Industry
- 2C: Metal Production
- 2D: Other Production
- 2E: Production of Halocarbons and SF_6
- 2F: Consumption of Halocarbons and SF_6
- 2G: Other

Sector 3: Solvent and Other Product Use

2006 Guidelines



Sector 2: Industrial Processes and Product Use

- 2A: Mineral Industry
- 2B: Chemical Industry
- 2C: Metal Industry
- 2D: Non-Energy Products from Fuels and Solvent Use
- 2E: Electronics Industry
- 2F: Product Uses as Substitutes for ODS
- 2G: Other Product Manufacture and Use
- 2H: Other

Improvement since 1996 Guidelines

- **Combined two sectors in the 1996 GLs**
- **Improved to explicitly include more manufacturing sectors and product uses identified as sources of GHGs**, e.g.:
  - Production of lead, zinc, titanium dioxide, petrochemicals, liquid crystal display (LCD), etc.
  - SF_6 and PFCs uses in military applications, accelerators, etc.

Formerly these emissions should have been estimated and reported in "2G Other", etc.

- **New gases, actual emission estimates**
  - Explained later.

Improvement since 1996 Guidelines

- Estimation of **actual annual emissions** instead of "**potential emissions**"
  - ✓ In the 1996 Guidelines and Good Practice Guidance for a few sources, the simplest methodology estimates a "potential emission" rather than the actual annual emission.
    - *This "potential emission" assumes all the emissions from an activity occur in the current year, ignoring the fact they will occur over many years (e.g. methane emissions from waste in landfills occurs over decades as the decay processes take place).*
  - ✓ In the 2006 Guidelines, simple default methods estimate emissions when they occur, thus removing the need for potential emissions.
  - ✓ The removal of potential emission estimates also allows the emission reductions of abatement techniques to be properly estimated.

Improvement since 1996 Guidelines

- **Demarcation between Energy and IPPU**
  - Clearer and practical guidance has been given.
- **Non-Energy Uses of Fossil Fuels**
  - Clearer guidance has been introduced on emissions from non-energy uses of fossil fuels (lubricants, paraffin waxes).
    - Emissions from primary use should be reported in IPPU.
    - Emissions from secondary fate should be reported in Energy (in case of combustion for heat/energy), or in Waste (in case of incineration at disposal sites).
  - A method has been introduced for checking the completeness of carbon dioxide emission estimates from the non-energy uses.

TABLE 1.2
TYPES OF USE AND EXAMPLES OF FUELS USED FOR NON-ENERGY APPLICATIONS

Type of use	Example of fuel types	Product/process	Chapter
Feedstock	natural gas, oils, coal	ammonia	3.2
	naphtha, natural gas, ethane, propane, butane, gas oil, fuel oils	methanol, olefins (ethylene, propylene), carbon black	3.9
Reductant	petroleum coke	carbides	3.6
	coal, petroleum coke	titanium dioxide	3.7
	metallurgical cokes, pulverised coal, natural gas	iron and steel (primary)	4.2
	metallurgical cokes	ferroalloys	4.3
	petroleum coke, pitch (anodes)	aluminium [1]	4.4
	metallurgical coke, coal	lead	4.6
	metallurgical coke, coal	zinc	4.7
Non-energy product	lubricants	lubricating properties	5.2
	paraffin waxes	misc. (e.g., candles, coating)	5.3
	bitumen (asphalt)	road paving and roofing	5.4
	white spirit[2], some aromatics	as solvent (paint, dry cleaning)	5.5

1. Also used in secondary steel production (in electric arc furnaces) (see Chapter 4.2).
2. Also known as mineral turpentine, petroleum spirits, industrial spirit ('SBP').

Gases

- A wide variety of gases
  - CO_2, CH_4, N_2O
  - HFCs, PFCs, SF_6
  - Other halogenated gases
  - Ozone/aerosol precursors (e.g., NMVOCs)
- H_2O and Gases controlled by the Montreal Protocol (e.g., CFCs, HCFCs) are not included.
- Under the UNFCCC, non-Annex I Parties:
  - should report CO_2, CH_4 and N_2O
  - are encouraged to report HFCs, PFCs, SF_6 and precursors
- New gases may emerge in the future.

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“New” gases in 2006 Guidelines – Sources Identified in 2006 Guidelines

By-product & fugitive emissions

	Electronics Industries	Magnesium production	Halogenated Compounds Production	GWP in TAR	GWP in AR4
nitrogen trifluoride (NF_3)	✓		✓	✓	✓
trifluoromethyl sulphur pentafluoride (SF_5CF_3)			✓	✓	✓
halogenated ethers (e.g. $C_4F_9OC_2H_5$, $CHF_2OCF_2OC_2F_4OCHF_2$, $CHF_2OCF_2OCHF_2$)	✓		✓	✓	✓
CF_3I, CH_2Br_2, $CHCl_3$			✓	✓	
CH_2Cl_2, CH_3Cl			✓	✓	✓
$C_3F_7C(O)C_2F_5$		✓	✓		
C_4F_6, C_5F_8, c-C_4F_8O	✓		✓		

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“New” gases

- “those for which either significant concentrations or large trends in concentrations have been observed or a clear potential for future emissions has been identified.” For example:
  - **Nitrogen Trifluoride (NF_3)**
    - Used in manufacture of LCD displays, photovoltaic cells
    - Currently 0.04 % of the impact of current human-produced CO_2 emissions
    - Current Concentration: 0.454 ppt
    - Increasing at 11 % per year
    - GWP (100 yr time horizon, 4AR) 17,200
  - **Trifluoromethyl Sulphur Pentafluoride (SF_5CF_3)**
    - By-product of fluorinated gas production other sources unknown (related to SF_6)
    - Current Concentration: 0.16-0.18 ppt
    - Increasing at 6.3 % per year
    - GWP (100 yr time horizon, 4AR) 17,700

Sources (For details, see the slides at the end of this file.)

- A wide variety of industries and products
  - Mineral industry
    - cement production, lime production, etc.
  - Chemical industry
    - ammonia production, nitric acid production, petrochemical production, fluorochemical production, etc.
  - Metal industry
    - iron and steel production, aluminium production, magnesium production, etc.
  - Non-energy products from fuels & solvent use
    - Lubricant use, paraffin wax use, solvent use, etc.

Sources (For details, see the slides at the end of this file.)

- A wide variety of industries and products
  - Electronics industry
    - semiconductor manufacturing, TFT flat panel display manufacturing, etc.
  - Product uses as ODS substitutes
    - refrigeration and air conditioning, foam blowing agents, fire protection, etc.
  - Other product manufacture and use
    - electrical equipment, medical applications, propellant for pressure and aerosol products, etc.
- New sources (new industries, new products) may emerge in the future.

TABLE 1.1
INDUSTRIAL PROCESSES AND PRODUCT USE CATEGORIES AND THEIR POSSIBLE EMISSIONS

2 Industrial Processes and Product Use (Note 1, 2)	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Other halo-genated Gases (Note3)
2A Mineral Industry							
2A1: Cement Production	X	*					
2A2: Lime Production	X	*					
2A3: Glass Production	X	*					
2A4: Other Process Uses of Carbonates							
2A4a: Ceramics	X	*					
2A4b: Other Uses of Soda Ash	X	*					
2A4c: Non Metallurgical Magnesia Production	X	*					
2A4d: Other	X	*					
2A5: Other	X	*	*				
2B Chemical Industry							
2B1: Ammonia Production	X	*	*				
2B2: Nitric Acid Production	*	*	X				
2B3: Adipic Acid Production	*	*	X				
2B4: Caprolactam, Glyoxal and Glyoxylic Acid Production	*	*	X				
2B5: Carbide Production	X	X	*				
2B6: Titanium Dioxide Production	X	*	*				
2B7: Soda Ash Production	X	*	*				
2B8: Petrochemical and Carbon Black Production							
2B8a: Methanol	X	X	*				
2B8b: Ethylene	X	X	*				
2B8c: Ethylene Dichloride and Vinyl Chloride Monomer	X	X	*				
2B8d: Ethylene Oxide	X	X	*				
2B8e: Acrylonitrile	X	X	*				
2B8f: Carbon Black	X	X	*				
2B9: Fluorochemical Production (Note 4)							
2B9a: By-product Emissions (Note 5)				X	X	X	X
2B9b: Fugitive Emissions (Note 5)				X	X	X	X
2B10: Other	*	*	*	*	*	*	*

TABLE 1.1
INDUSTRIAL PROCESSES AND PRODUCT USE CATEGORIES AND THEIR POSSIBLE EMISSIONS

2 Industrial Processes and Product Use (Note 1, 2)	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Other halo-genated Gases (Note3)
2C Metal Industry							
2C1: Iron and Steel Production	X	X	*				
2C2: Ferroalloys Production	X	X	*				
2C3: Aluminium Production	X	*			X		
2C4: Magnesium Production (Note 6)	X			X	X	X	X
2C5: Lead Production	X						
2C6: Zinc Production	X						
2C7: Other	*	*	*	*	*	*	*
2D Non-Energy Products from Fuels and Solvent Use (Note 7)							
2D1: Lubricant Use	X						
2D2: Paraffin Wax Use	X	*	*				
2D3: Solvent Use (Note 8)							
2D4: Other (Note 9)	*	*	*				
2E Electronics Industry							
2E1: Integrated Circuit or Semiconductor (Note 10)	*		*	X	X	X	X
2E2: TFT Flat Panel Display (Note 10)				X	X	X	X
2E3: Photovoltaics (Note 10)				X	X	X	X
2E4: Heat Transfer Fluid (Note 11)							X
2E5: Other	*	*	*	*	*	*	*

TABLE 1.1 (CONTINUED)
INDUSTRIAL PROCESSES AND PRODUCT USE CATEGORIES AND THEIR POSSIBLE EMISSIONS

2 Industrial Processes and Product Use (Note 1, 2)	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Other halo-genated Gases (Note 3)
2F Product Uses as Substitutes for Ozone Depleting Substances							
2F1: Refrigeration and Air Conditioning							
2F1a: Refrigeration and Stationary Air Conditioning	*			X	X		*
2F1b: Mobile Air Conditioning	*			X	X		*
2F2: Foam Blowing Agents	*			X	*		*
2F3: Fire Protection	*			X	X		*
2F4: Aerosols				X	X		*
2F5: Solvents (Note 12)				X	X		*
2F6: Other Applications	*	*	*	X	X		*
2G Other Product Manufacture and Use							
2G1: Electrical Equipment							
2G1a: Manufacture of Electrical Equipment (Note 13)					X	X	*
2G1b: Use of Electrical Equipment (Note 13)					X	X	*
2G1c: Disposal of Electrical Equipment (Note 13)					X	X	*
2G2: SF_6 and PFCs from Other Product Uses							
2G2a: Military Applications					*	X	*
2G2b: Accelerators (Note 14)					*	X	*
2G2c: Other					X	X	*
2G3: N_2O from Product Uses							
2G3a: Medical Applications			X				
2G3b: Propellant for Pressure and Aerosol Products			X				
2G3c: Other			X				
2G4: Other	*	*		*			*
2H Other							
2H1: Pulp and Paper Industry (Note 15)	*	*					
2H2: Food and Beverages Industry (Note 15)	*	*					
2H3: Other	*	*	*				

Features

- **Diversity of sources and gases**
  - Difficult to exhaustively include all sources & gases
  - Identify and include major sources & gases at least
- **Various opportunities for GHG abatement**
  - Capture and abatement at plants (e.g., N_2O destruction at nitric acid production plants)
  - Recovery at the end of product's life and subject to either recycled or destroyed (e.g., HFCs in refrigerators)
- **Care required in treating confidential data obtained from private sectors**

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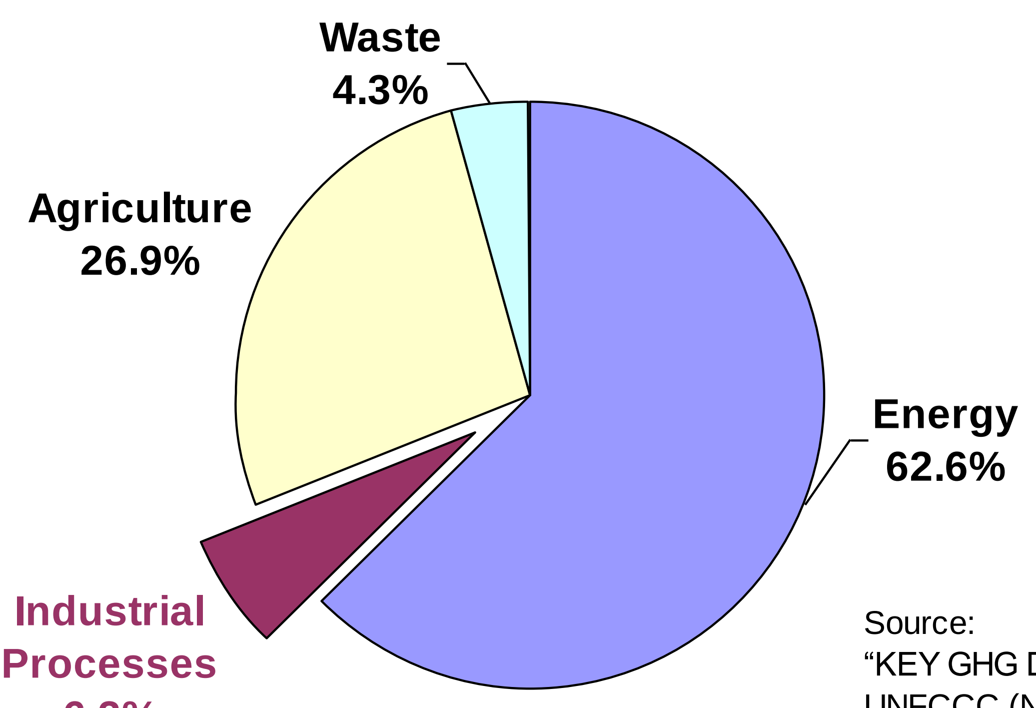
Restricted data and confidentiality

- Data providers might restrict access to information because it is confidential, unpublished, or not yet finalised.
- Find solutions to overcome their concerns by:
  - ✓ explaining the intended use of the data,
  - ✓ agreeing, in writing, to the level at which it will be made public,
  - ✓ identifying the increased accuracy that can be gained through its use in inventories,
  - ✓ offering cooperation to derive a mutually acceptable data sets,
  - ✓ and/or giving credit/acknowledgement in the inventory to the data provided.

Importance for Non-Annex I Parties

- Tends to be considered less significant as compared to Energy and Agriculture

Breakdown of GHG emissions (CO_2, CH_4 & N_2O, without LUCF) from non-Annex I Parties by sector for 1994



Source:
"KEY GHG DATA" published by UNFCCC (November 2005)

Importance for Non-Annex I Parties

- Situation varies from country to country.
  - e.g., Peru reported 17.2% of GHGs was from Industrial Processes in 1994
- Significance of these sources may become greater in the future as development goes on.
- IP Sector emission estimation is important to find and make use of opportunities for GHG abatement.

How to estimate GHG emissions

- Typical Tier 1 – basic equation & default EF

> Emission = AD x EF
>
> AD: Activity level data
> (e.g., amount of material produced or consumed)
>
> EF: Emission factor
> (emission per unit of production or consumption)

- For some sources, a little more complex equation is used. See the IPCC Guidelines.
- Tier 2 (and 3): More detailed methods using:
  - Country-specific or plant-specific EFs
  - Direct measurement emission data
  - Data on GHG abatement / etc.

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Chapter 2: Mineral Industry

- Two pathways for CO_2 from carbonates
  - Calcination: e.g. $CaCO_3$ + heat → $CaO + CO_2$
  - Acid-induced release: e.g. $CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2$

Code	Category
2A1:	Cement Production
2A2:	Lime Production
2A3:	Glass Production
2A4:	Other Process Uses of Carbonates
2A4a:	Ceramics
2A4b:	Other Uses of Soda Ash
2A4c:	Non Metallurgical Magnesia Production
2A4d:	Other
2A5:	Other

Chapter 2: Mineral Industry

- Consistent approach based on carbonate content of inputs for all sources
- Inclusion of new guidance for other carbonates

TABLE 2.1
FORMULAE, FORMULA WEIGHTS, AND CARBON DIOXIDE CONTENTS OF COMMON CARBONATE SPECIES*

Carbonate	Mineral Name(s)	Formula Weight	Emission Factor (tonnes CO_2/tonne carbonate)**
$CaCO_3$	Calcite*** or aragonite	100.0869	0.43971
$MgCO_3$	Magnesite	84.3139	0.52197
$CaMg(CO_3)_2$	Dolomite***	184.4008	0.47732
$FeCO_3$	Siderite	115.8539	0.37987
$Ca(Fe,Mg,Mn)(CO_3)_2$	Ankerite****	185.0225–215.6160	0.40822–0.47572
$MnCO_3$	Rhodochrosite	114.9470	0.38286
Na_2CO_3	Sodium carbonate or soda ash	106.0685	0.41492

Source: CRC Handbook of Chemistry and Physics (2004)

* Final results (i.e., emission estimates) using these data should be rounded to no more than two significant figures.

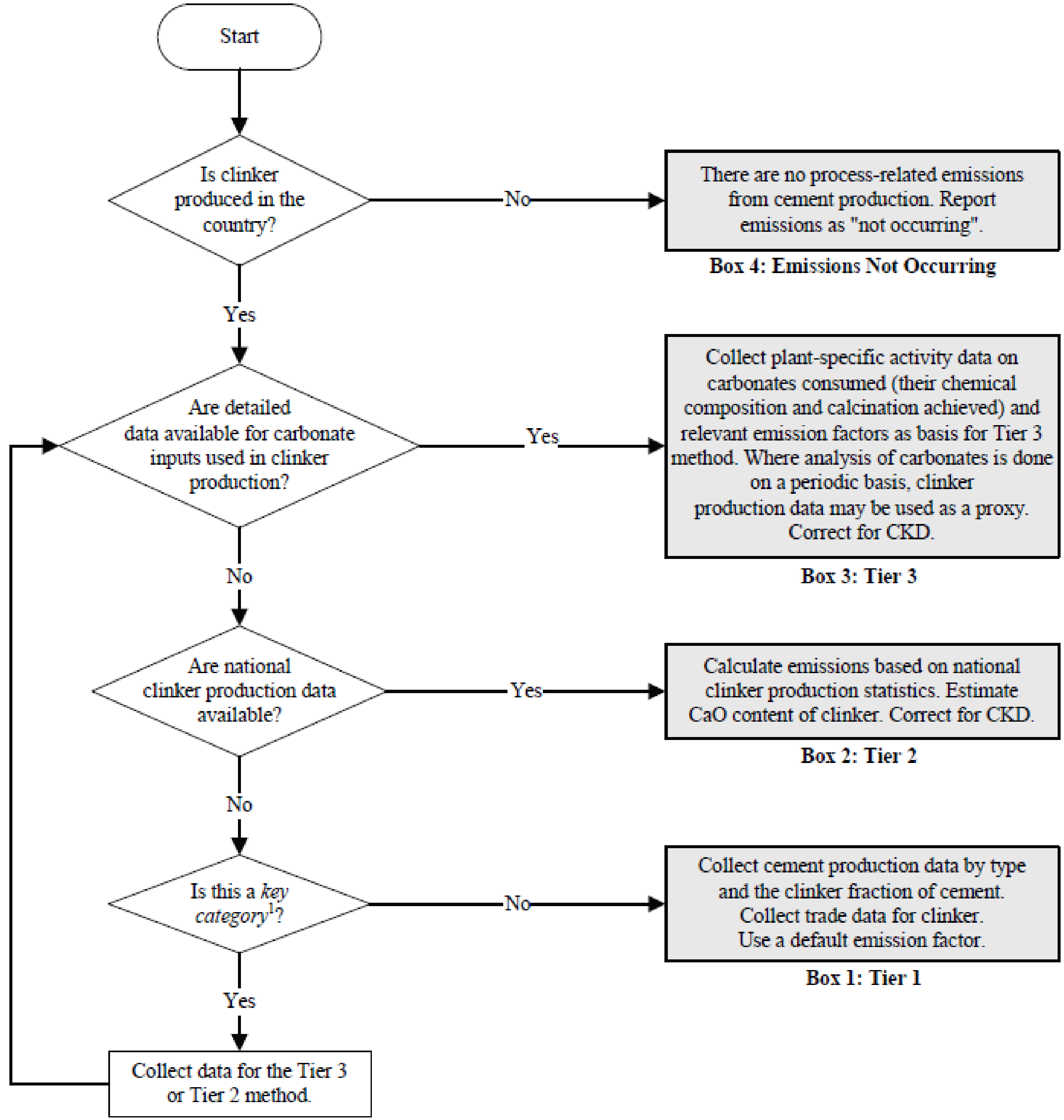
** The fraction of emitted CO_2 assuming 100 percent calcination; e.g., 1 tonne calcite, if fully calcined, would yield 0.43971 tonnes of CO_2.

*** Calcite is the principal mineral in limestone. Terms like high-magnesium or dolomitic limestones refer to a relatively small substitution of Mg for Ca in the general $CaCO_3$ formula commonly shown for limestone.

**** Formulae weight range shown for ankerite assumes that Fe, Mg, and Mn are present in amounts of at least 1.0 percent.

CO_2 from Cement Production

Figure 2.1 Decision tree for estimation of CO_2 emissions from cement production



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CO_2 from Cement Production (Tier 1)

$$E_{CO2} = [\Sigma_i(M_{c,i} \times C_{cl,i}) - Im + Ex] \times EF_{clc}$$

E_{CO2} = CO_2 emissions from cement production, tonnes

$M_{c,i}$ = mass of cement produced of type *i*, tonnes

$C_{cl,i}$ = clinker fraction of cement type *i*, fraction

Im = imports for consumption of clinker, tonnes

Ex = exports of clinker, tonnes

EF_{clc} = emission factor for clinker, tonnes CO_2/tonne clinker

- Default EF_{clc} = 0.52
  - Already corrected for cement kiln dust (CKD)
- "Activity data" is clinker production

  $= [\Sigma_i(M_{c,i} \times C_{cl,i}) - Im + Ex]$

CO_2 from Cement Production (Tier 1)

- To estimate clinker production:
  - National-level data should be collected on:
    - Cement production by type (Portland, masonry, etc.)
    - Clinker fraction by cement type
  - If detailed information on cement type is not available, multiply total cement production by:
    - Default Ccl = 0.75 (if blended/'masonry' is much)
    - Default Ccl = 0.95 (if all is essentially 'Portland')
  - Data should be obtained on the amount of clinker imported and exported.

CO_2 from Cement Production (Tier 2)

$$E_{CO2} = M_{cl} \times EF_{cl} \times CF_{ckd}$$

E_{CO2} = CO_2 emissions from cement production, tonnes

M_{cl} = mass of clinker produced, tonnes

EF_{cl} = emission factor for clinker, tonnes CO_2/tonne clinker

CF_{cl} = emissions correction factor for CKD, dimensionless

- CKD not recycled to the kiln is considered to be 'lost' and associated emissions are not accounted for by the clinker.

EQUATION 2.5
CORRECTION FACTOR FOR CKD NOT RECYCLED TO THE KILN

$$CF_{ckd} = 1 + (M_d / M_{cl}) \bullet C_d \bullet F_d \bullet (EF_c / EF_{cl})$$

Where:

CF_{ckd} = emissions correction factor for CKD, dimensionless

M_d = weight of CKD not recycled to the kiln, tonnes[a]

M_{cl} = weight of clinker produced, tonnes

C_d = fraction of original carbonate in the CKD (i.e., before calcination), fraction[b]

F_d = fraction calcination of the original carbonate in the CKD, fraction[b]

EF_c = emission factor for the carbonate (Table 2.1), tonnes CO_2/tonne carbonate

EF_{cl} = emission factor for clinker uncorrected for CKD (i.e., 0.51 tonnes CO_2/tonne clinker), tonnes CO_2/tonne clinker

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CO_2 from Cement Production (Tier 3)

EQUATION 2.3

TIER 3: EMISSIONS BASED ON CARBONATE RAW MATERIAL INPUTS TO THE KILN

$$CO_2\ Emissions = \underbrace{\sum_i (EF_i \bullet M_i \bullet F_i)}_{\text{Emissions from carbonates}} - \underbrace{M_d \bullet C_d \bullet (1 - F_d) \bullet EF_d}_{\text{Emissions from uncalcined CKD not recycled to the kiln}} + \underbrace{\sum_k (M_k \bullet X_k \bullet EF_k)}_{\text{Emissions from carbon-bearing non-fuel materials}}$$

Where:

CO_2 Emissions = emissions of CO_2 from cement production, tonnes

EF_i = emission factor for the particular carbonate *i*, tonnes CO_2/tonne carbonate (see Table 2.1)

M_i = weight or mass of carbonate *i* consumed in the kiln, tonnes

F_i = fraction calcination achieved for carbonate *i*, fraction[a]

M_d = weight or mass of CKD not recycled to the kiln (= 'lost' CKD), tonnes

C_d = weight fraction of original carbonate in the CKD not recycled to the kiln, fraction[b]

F_d = fraction calcination achieved for CKD not recycled to kiln, fraction[a]

EF_d = emission factor for the uncalcined carbonate in CKD not recycled to the kiln, tonnes CO_2/tonne carbonate[b]

M_k = weight or mass of organic or other carbon-bearing nonfuel raw material *k*, tonnes[c]

X_k = fraction of total organic or other carbon in specific nonfuel raw material *k*, fraction[c]

EF_k = emission factor for kerogen (or other carbon)-bearing nonfuel raw material *k*, tonnes CO_2/tonne carbonate[c]

Chapter 3: Chemical Industry

- Separation of CO_2 from urea use and production
- Various "new" sources added
- Soda Ash Production is included (formerly under 2A)
- Expanded method for HFC-23 and other F-gases by-product

Code	Category	Code	Category
2B1:	Ammonia Production	2B8b:	Ethylene
2B2:	Nitric Acid Production	2B8c:	Ethylene Dichloride and Vinyl Chloride Monomer
2B3:	Adipic Acid Production	2B8d:	Ethylene Oxide
2B4:	Caprolactam, Glyoxal and Glyoxylic Acid Production	2B8e:	Acrylonitrile
2B5:	Carbide Production	2B8f:	Carbon Black
2B6:	Titanium Dioxide Production	2B9:	Fluorochemical Production
2B7:	Soda Ash Production	2B9a:	By-product Emissions
2B8:	Petrochemical and Carbon Black Production	2B9b:	Fugitive Emissions
2B8a:	Methanol	2B10:	Other

Chapter 3: Chemical Industry

- CO_2 associated with urea production & use
  - Formerly, all these were implicitly included in CO_2 from Ammonia Production.
  - CO_2 recovered in the ammonia production process for urea production should be deducted from CO_2 emissions from 2B1 Ammonia Production.
  - CO_2 emissions from urea use/incineration should be reported in the category where they occur: e.g.,
    - Use of urea-based catalysts (Energy Sector)
    - Urea application to agricultural soils (AFOLU Sector)
    - Incineration of urea-based products (Waste Sector)
  - Thus, now, proper account can be taken for exports of urea produced in ammonia plants.

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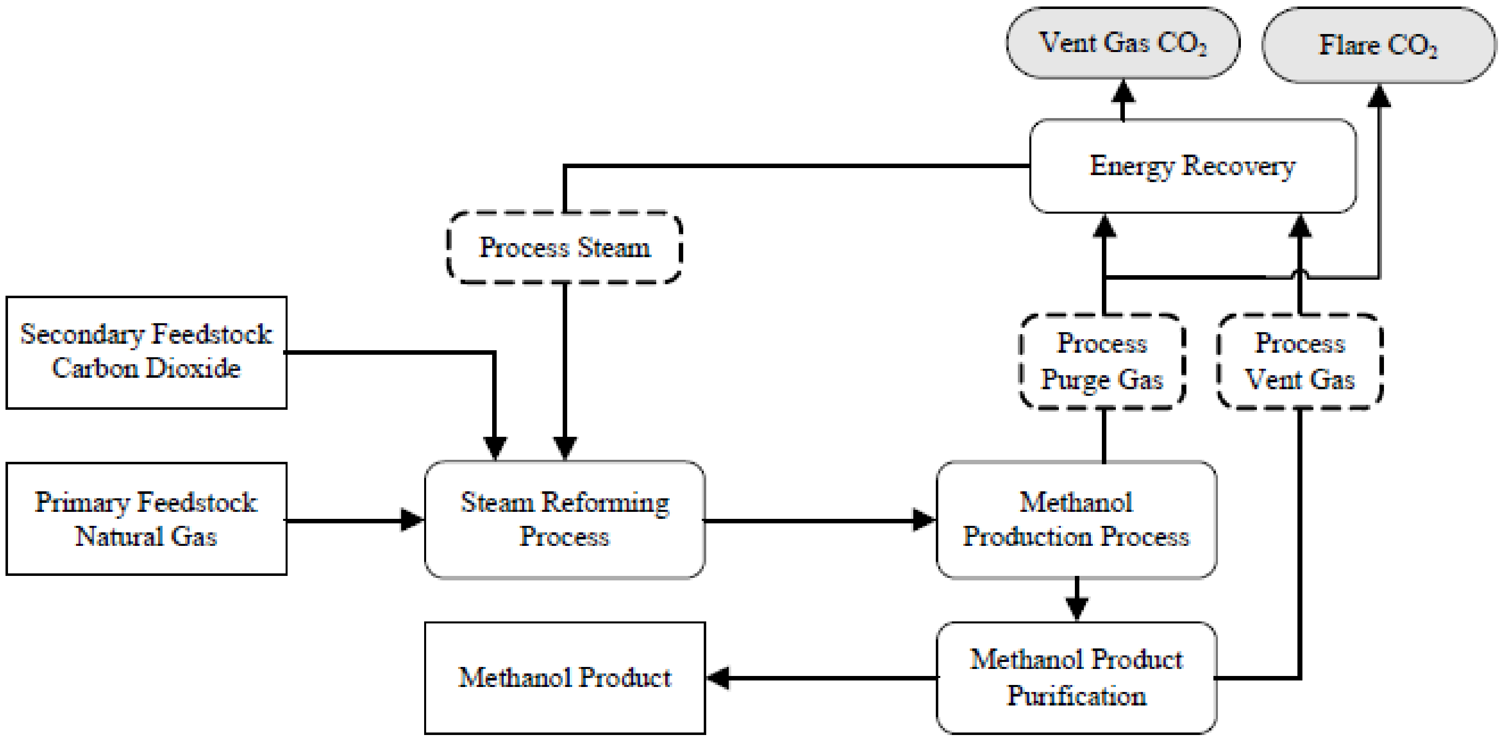
Emissions from petrochemical and carbon black production

e.g., methanol production

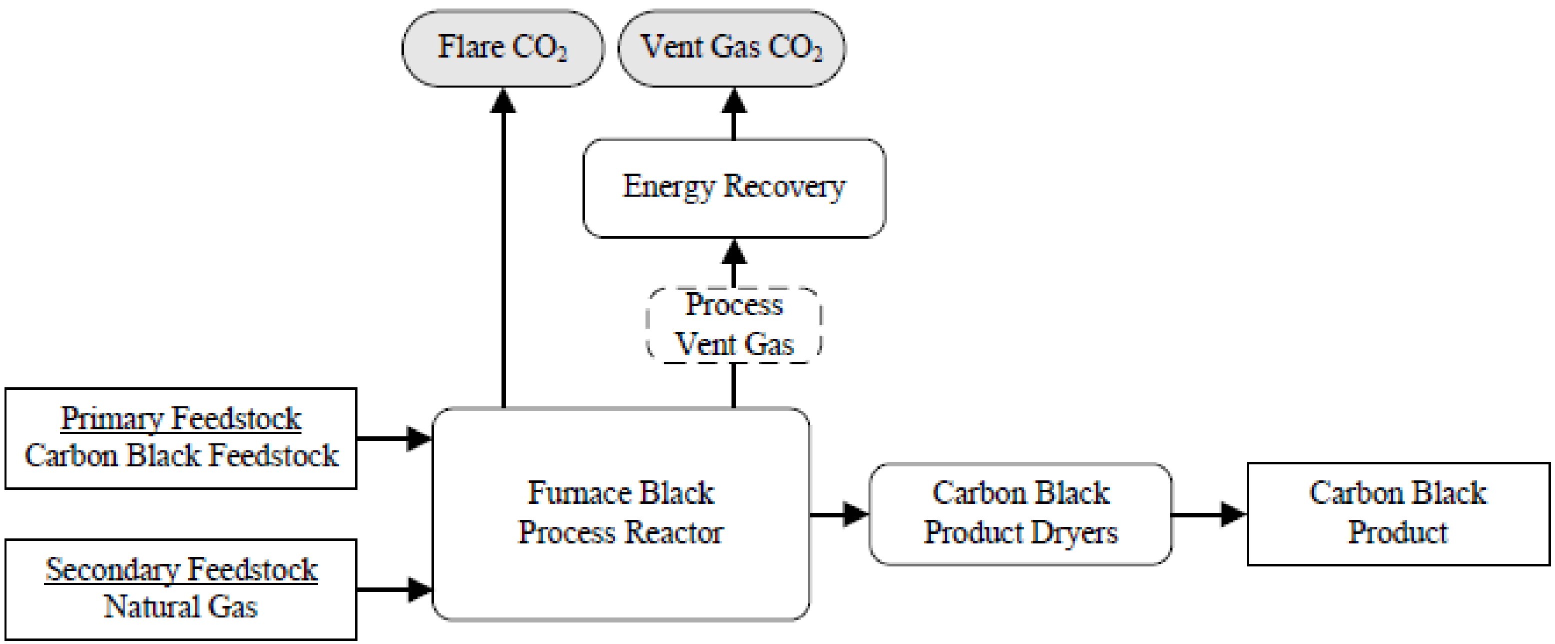
Figure 3.11 Methanol production feedstock-product flow diagram



Emissions from petrochemical and carbon black production

e.g., carbon black production

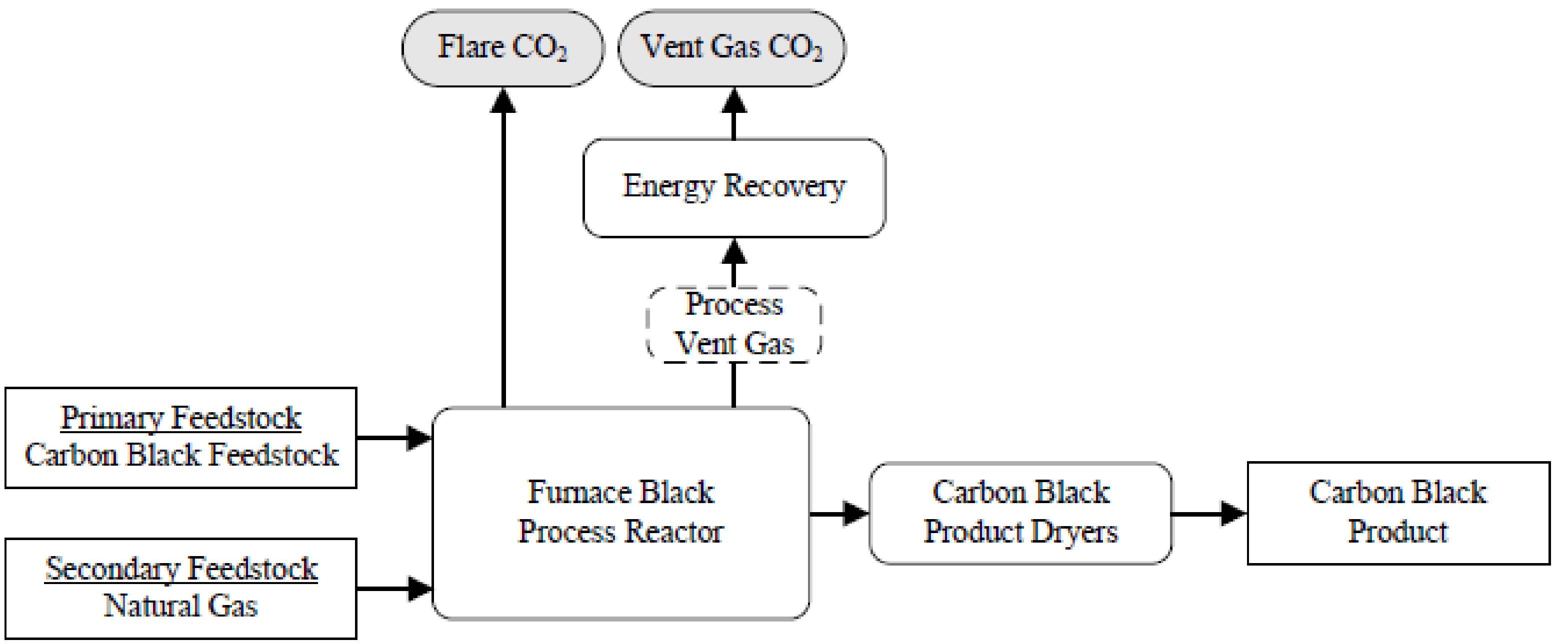
Figure 3.15 Carbon black production feedstock-product flow diagram



Emissions from petrochemical and carbon black production

e.g., carbon black production

Figure 3.15 Carbon black production feedstock-product flow diagram



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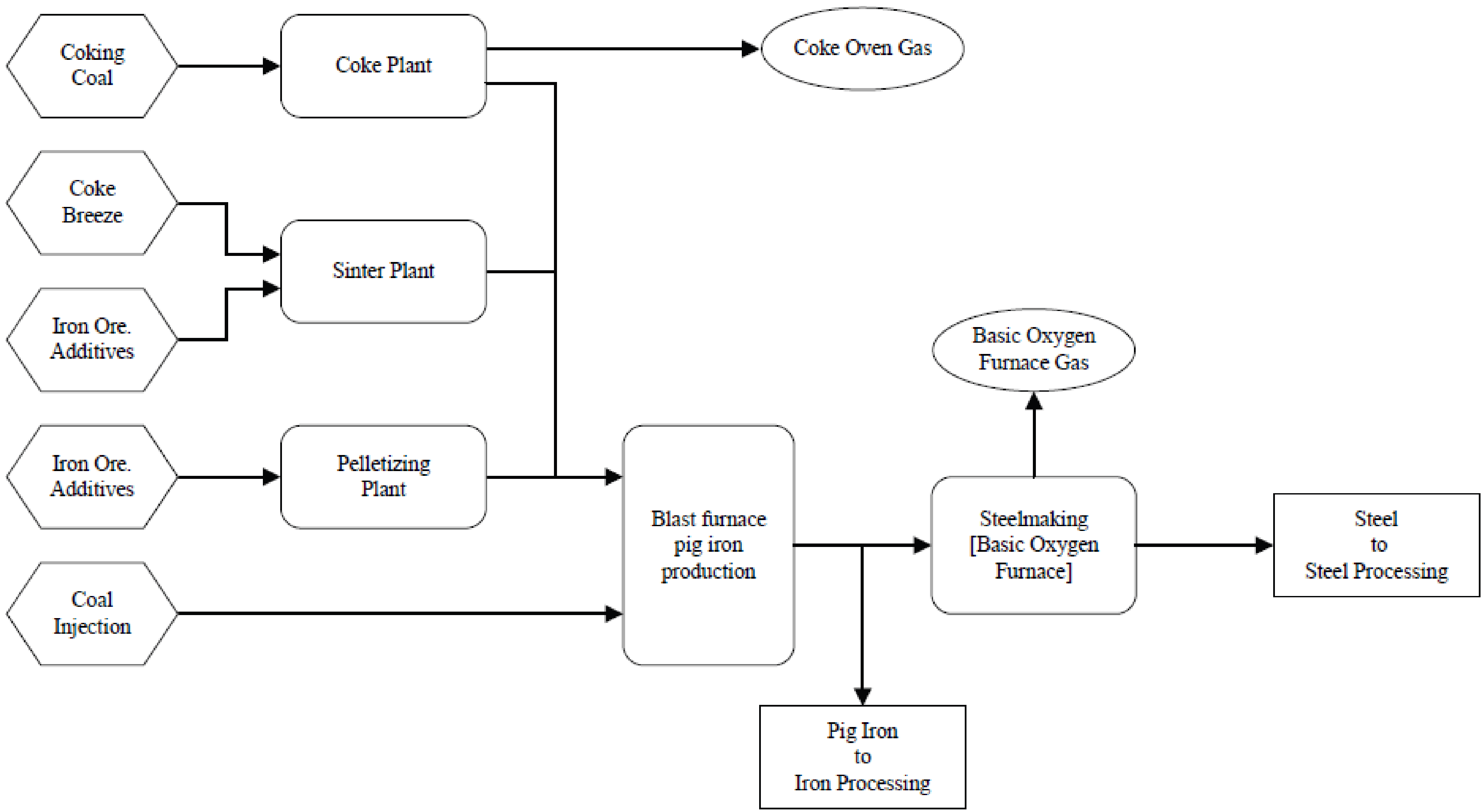
Chapter 4: Metal Industry

- Detailed treatment of different production routes for iron and steel including DRI and metallurgical coke (Emissions from metallurgical coke should be reported under Energy Sector.)
- Improved guidance on production of ferroalloys
- New guidance on zinc and lead production

Code	Category
2C1:	Iron and Steel Production
2C2:	Ferroalloys Production
2C3:	Aluminium Production
2C4:	Magnesium Production
2C5:	Lead Production
2C6:	Zinc Production
2C7:	Other

CO_2 from Iron & Steel Production

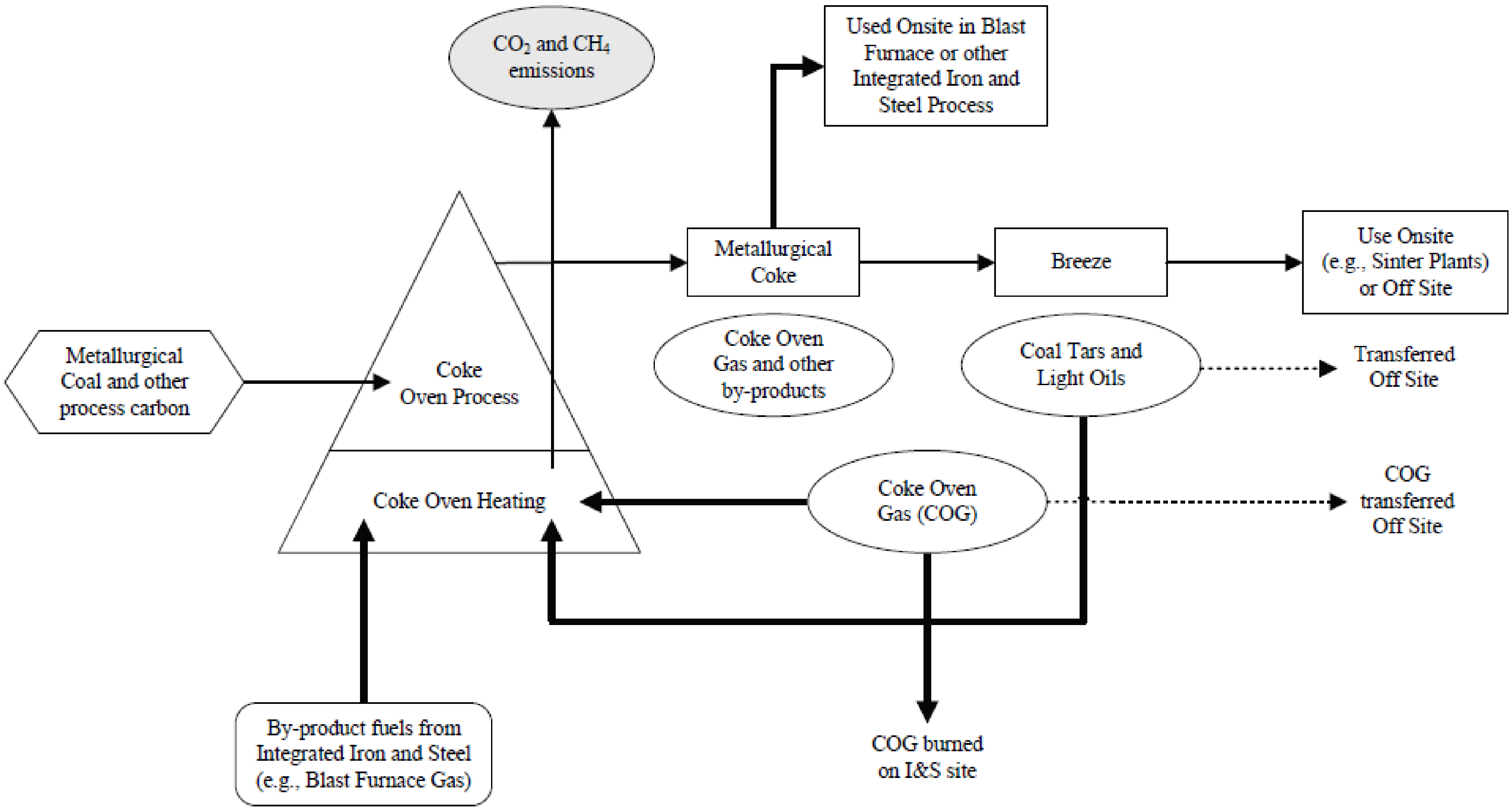
Figure 4.1 Illustration of main processes for integrated iron and steel production*



* Modified from: European Conference on "The Sevilla Process: A Driver for Environmental Performance in Industry" Stuttgart, 6 and 7 April 2000, BREF on the Production of Iron and Steel - conclusion on BAT, Dr. Harald Schoenberger, Regional State Governmental Office Freiburg, April 2000. (Schoenberger, 2000)

CO_2 from Iron & Steel Production

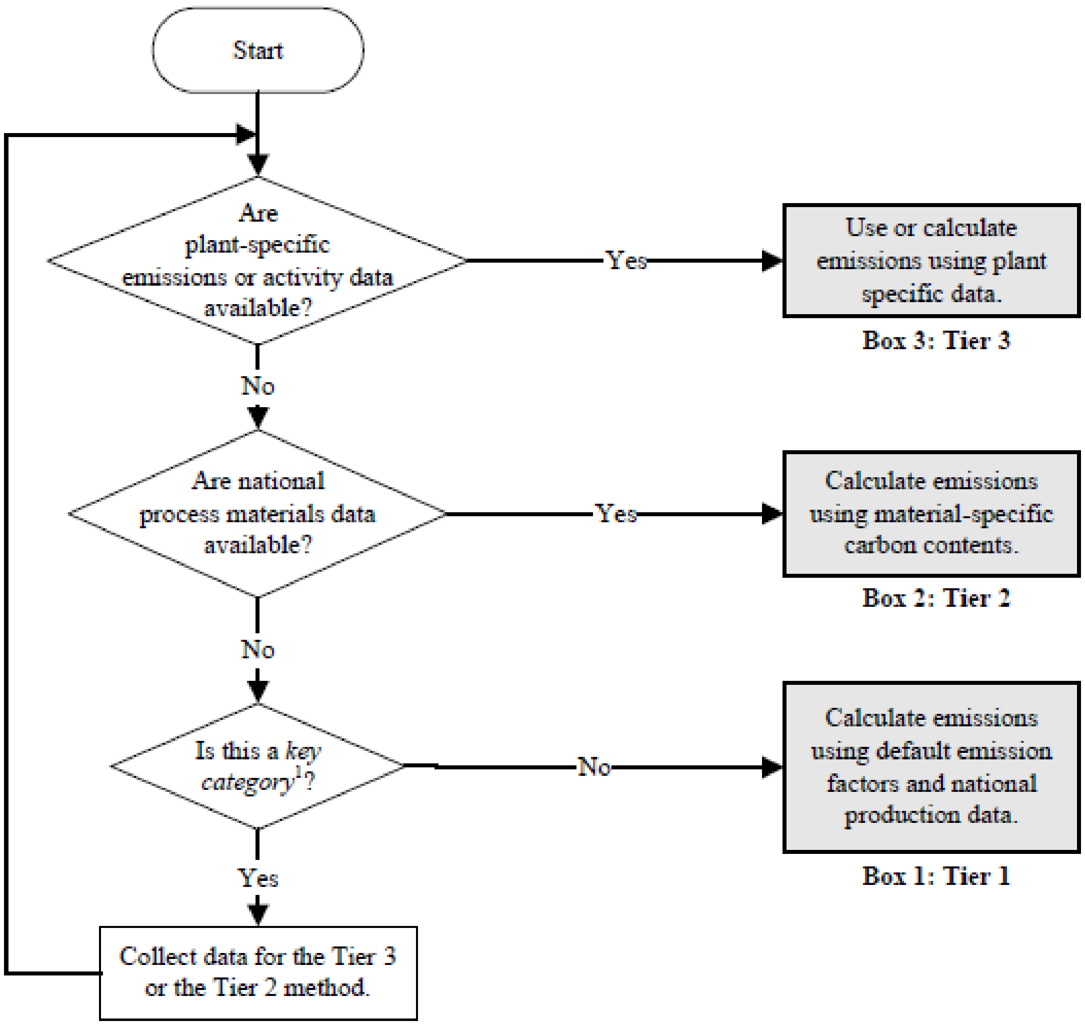
Figure 4.2 Illustration of coke production process (emissions reported in Category 1A of the Energy Sector)



Note:
Bold lines apply only to Onsite Coke Production at Integrated Iron and Steel Mill. Dashed lines apply to transfers of materials to 'Off Site processes.' 'Off Site process' does not include Integrated Iron and Steel production processes, which are categorised as Onsite.

CO_2 from Iron & Steel Production

Figure 4.7 Decision tree for estimation of CO_2 emissions from iron and steel production



Note:
1. See Volume 1 Chapter 4, Methodological Choice and Identification of Key Categories (noting Section 4.1.2 on limited resources), for discussion of *key categories* and use of decision trees.

CO_2 from Iron and Steel Production (Tier 1)

$$E_{CO2} = \sum_i (AD_i \times EF_i)$$

E_{CO2} = CO_2 emissions from iron & steel production, tonnes

AD_i = quantity of material *i*, tonnes

EF_i = emission factor for production of material *i*, tonnes CO_2/tonne material *i* produced

Material *i* to be included:

- Crude steel from Basic Oxygen Furnace (BOF)
- Crude steel from Electric Arc Oxygen Furnace (EAF)
- Crude steel from Open Hearth Furnace (OHF)
- Pig iron not converted to steel
- Direct reduced iron (DRI)
- Sinter
- Pellet

CO_2 from Iron and Steel Production (Tier 1)

- Emissions from metallurgical coke production should be reported in Energy Sector.
- Default EFs are:
  - BOF steel: 1.46 t-CO_2/t
  - EAF steel: 0.08 t-CO_2/t
  - OHF steel: 1.72 t-CO_2/t
  - Pig iron: 1.35 t-CO_2/t
  - DRI: 0.70 t-CO_2/t
  - Sinter: 0.20 t-CO_2/t
  - Pellet: 0.03 t-CO_2/t

Global average default = 1.06 t-CO_2/t

(If activity data on steel production for each process is not available, multiply total steel production by this EF.)

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CO_2 from Iron and Steel Production (Tier 2)

EQUATION 4.9
CO_2 EMISSIONS FROM IRON & STEEL PRODUCTION (TIER 2)

$$E_{CO2,non-energy} = \Big[PC \bullet C_{PC} + \sum_a (COB_a \bullet C_a) + CI \bullet C_{CI} + L \bullet C_L + D \bullet C_D + CE \bullet C_{CE} + \sum_b (O_b \bullet C_b) + COG \bullet C_{COG} - S \bullet C_S - IP \bullet C_{IP} - BG \bullet C_{BG}\Big] \bullet \frac{44}{12}$$

Where, for iron and steel production:

$E_{CO2,\ non\text{-}energy}$ = emissions of CO_2 to be reported in IPPU Sector, tonnes

PC = quantity of coke consumed in iron and steel production (not including sinter production), tonnes

COB_a = quantity of onsite coke oven by-product *a*, consumed in blast furnace, tonnes

CI= quantity of coal directly injected into blast furnace, tonnes

L = quantity of limestone consumed in iron and steel production, tonnes

D = quantity of dolomite consumed in iron and steel production, tonnes

CE = quantity of carbon electrodes consumed in EAFs, tonnes

O_b = quantity of other carbonaceous and process material *b*, consumed in iron and steel production, such as sinter or waste plastic, tonnes

COG= quantity of coke oven gas consumed in blast furnace in iron and steel production, m^3 (or other unit such as tonnes or GJ. Conversion of the unit should be consistent with Volume 2: Energy)

S = quantity of steel produced, tonnes

IP = quantity of iron production not converted to steel, tonnes

BG = quantity of blast furnace gas transferred offsite, m^3 (or other unit such as tonnes or GJ. Conversion of the unit should be consistent with Volume 2: Energy)

C_x = carbon content of material input or output *x*, tonnes C/(unit for material *x*) [e.g., tonnes C/tonne]

Chapter 5: Non-Energy Products from Fuels and Solvent Use

- Inclusion of previously separate sector on solvent use
- Consideration of use of fuels as lubricants, paraffin waxes, bitumen/asphalt and solvents
- Focuses on direct CO_2 emissions

Code	Category
2D1:	Lubricant Use
2D2:	Paraffin Wax Use
2D3:	Solvent Use
2D4:	Other

Chapter 6: Electronics Industry

- Added guidance on production of PV cells, LCD and heat transfer fluids
- Inclusion of new gases applied in the industry
- Update of emission factors – including treatment of abatement
- Inclusion of a new tier 1 method providing emission factors & activity data

Code	Category
2E1:	Integrated Circuit or Semiconductor
2E2:	TFT Flat Panel Display
2E3:	Photovoltaics
2E4:	Heat Transfer Fluid
2E5:	Other

Chapter 7: Fluorinated Substitutes for ODS

- Tier 1 approach on "actual emissions" instead of "potential emissions"

Code	Category
2F1:	Refrigeration and Air Conditioning
2F1a:	Refrigeration and Stationary Air Conditioning
2F1b:	Air Conditioning
2F2:	Foam Blowing Agents
2F3:	Fire Protection
2F4:	Aerosols
2F5:	Solvents
2F6:	Other Applications

Emissions of Fluorinated Substitutes for Ozone Depleting Substance (Refrigeration)

- Sector includes
  - Commercial and Domestic Refrigeration
  - Commercial and Domestic Air Conditioning
  - Industrial Processes (chillers, cold storage, heat pumps etc.)
  - Vehicular Air Conditioning (cars, buses, trains)
- Emissions occur from:
  - Leakage from equipment in use
  - Retirement – scrapping of old equipment

Potential Emission & Actual Emission

- Two approaches to estimating emissions from F-gas consumption
  - ✓ **Potential emission** estimates
    - Assumes all the emissions from an activity occur in the current year, ignoring the fact they will occur over many years

TABLE A2.1 CALCULATION SCHEME FOR POTENTIAL EMISSIONS ACCORDING TO THE FORMER TIER 1a
REPORTING YEAR:
TYPE OF CHEMICAL (e.g., HFC-134a):
Production of chemical + Import of chemical in bulk – Export of chemical in bulk – Destruction of chemical = Sum (potential emission of chemical)

Better!!

  - ✓ **Actual emission** estimates
    - Estimates emissions that actually occur in the current year.

1996 Guidelines	Tier 1 = Potential Emission Tier 2 = Actual Emission
2006 Guidelines	Tier 1, Tier 2 = Actual Emission Potential Emission approach is used only for verification.

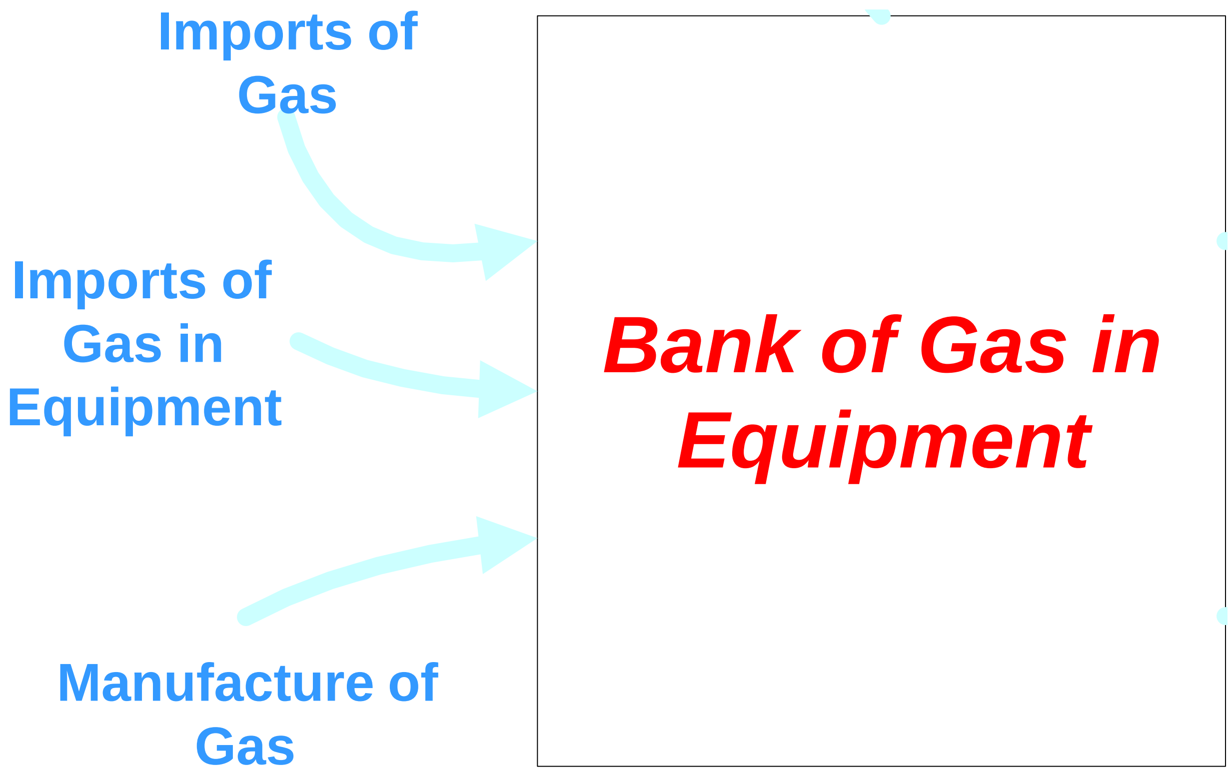
Actual Emission Estimates

- Why are actual emission estimates better than potential emission estimates…? That is because:
  - ✓ It takes into account the time lag between consumption and emission, which may be considerable in some application areas, e.g., refrigeration.
  - ✓ Time lag results from the fact that a chemical is placed in new products and then slowly leaks out over many years.

Potential emission estimates do not take this fact into account at all!!

"Bank"

Total amount of substances contained in existing equipment, chemical stockpiles, foams and other products not yet released to the atmosphere



Difficulties

- However, estimation of actual emissions is not as easy as potential emissions, because it has to take the "bank" into account, which requires:
  - ✓ Complex calculation as compared to very simple equation for potential emission estimates

This can be overcome by the software.

$$Emissions_t = Bank_t \bullet EF + RRL_t$$

and

$$Bank_t = \sum_{i=t_0}^{t} \left(Production_i + Imports_i - Exports_i - Destruction_i - Emissions_{i-1} \right) - RRL_t$$

  - ✓ Historic data on production, exports, imports, etc of chemicals (cf., potential emission estimates require only the current year data)

What about this difficulty…? Can we overcome it, too?

Yes, we can!!

- New IPCC software enables you to estimate actual emissions even if you do not have historic data – if you have at least the data/information on:
  - Year of introduction of agent
  - Domestic production of agent in current year
  - Imports of agent in current year
  - Exports of agent in current year
  - Growth rate of sales of equipment that uses the agent

✓ For example, in the case the data are available only for 2005 and 2010 while you know the chemical has been used since 1995…

(tonne)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Produced Quantity											26091					27925
Exported Quantity											18046					23963
Imported Quantity											9287					17222

Data will be automatically estimated using an empirical assumption.

Data will be automatically estimated using interpolation.

Empirical assumption…

- In the absence of historic data on production, imports and exports, the calculations assume that the total market for equipment grows exponentially while the share of the market which is taken by the F-gas grows linearly between the year of introduction and the current year.

$$M(t+1) = (1+r) \times M(t) \times (t - t_0 + 2)/(t - t_0 + 1)$$

M(t) = Production, Exports or Imports of F-gas in year **t**

r = Growth rate of sales of equipment that uses the agent (fraction)

t_0 = Year of introduction of agent

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Chapter 8: Other Product Manufacture and Use

- SF_6 (and PFCs) from electrical equipment:
  - Replacement of three parallel Tier 3 mass balance methods by one flexible method
  - New tier 1 emission factors for regions and technologies
- Other sources: e.g. nuclear fuel cycle, military applications

Code	Category	Code	Category
2G1:	Electrical Equipment	2G2c:	Other
2G1a:	Manufacture	2G3:	N_2O from Product Uses
2G1b:	Use	2G3a:	Medical Applications
2G1c:	Disposal	2G3b:	Propellant for Pressure and Aerosol Products
2G2:	SF_6 and PFCs from Other Product Uses	2G3c:	Other
2G2a:	Military Applications	2G4:	Other
2G2b:	Accelerators		

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Any questions?

Please note:
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