Industrial Processes and Product Use (IPPU)

Africa Regional Workshop on the Building of Sustainable National Greenhouse Gas Inventory Management Systems, and the Use of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

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Outline

1. IPPU importance
2. What is the IPPU Sector?
3. IPPU Categories:
   - 2A: Mineral Industry
   - 2B: Chemical Industry
   - 2C: Metal Industry
   - 2D: Non-Energy Products from Fuels & Solvent Use
   - 2E: Electronics Industry
   - 2F: Product Uses as Substitutes for Ozone Depleting Substances
   - 2G: Other Product Manufacture and Use (Electrical Eq., Military Apps, Medical Apps)
4. Data and Cross-Checks
5. Conclusion

Importance for Non-Annex I Parties

- IPPU sector is considered to be less significant compared to Energy and AFOLU
- Situation varies from country to country
- IPPU sources may become significant in the future as developing countries' economies and industries grow
- Inclusion of F-gases estimates can contribute significantly to the IPPU emissions and influence the total estimates
- IPPU emissions estimation is important to find opportunities for GHG abatement

IPPU Sector

IPPU – GHG emissions:

1. Industrial Processes
2. Product Use

1. Industrial Processes that chemically or physically transform materials releasing GHG:

- chemically: $NH_3 + O_2 = 0.5\ N_2O\uparrow + 1.5\ H_2O$ *(nitric acid production)*
- physically: $CaCO_3$ + (Heat) = $CaO + CO_2\uparrow$

2. Product Use: GHGs are used in products such as refrigerators, foams or aerosol cans

Note: significant time can elapse between the manufacture of the product and the release of GHG. The delay can vary from a few weeks (e.g., for aerosol cans) to several decades (e.g., rigid foams). In refrigeration a fraction of GHG used in the products can be recovered at the end of product's life and either recycled or destroyed.

IPPU Sector

Not IPPU:

- **Emissions from Fuel combustion in Industrial Sector for energy purposes** (*e.g., cement production*) → **Energy Sector**

- **Fugitive emissions in Oil/Gas industries** → **Energy Sector**

- **Solvents & other products incineration without energy recovery** → **Waste Sector**

Demarcation: IPPU vs. Energy

Combustion emissions from fuels obtained from the feedstock for an IPPU process will normally be allocated the source category in which the process occurs (*these source categories are normally 2B and 2C*). However, if the derived fuels are transferred for combustion in another source category, the emissions should be reported in the appropriate part of the Energy Sector (*normally 1A1 or 1A2*).

Example:

if blast furnace gas is combusted entirely within the Iron and Steel industry (whether for heating blast air, site power needs or for metal finishing operations) the associated emissions are reported in the IPPU source subcategory 2C1. If part of the gas is delivered to a nearby brick works for heat production or a main electricity producer then the emissions are reported in the Energy source subcategories (1A2f or 1A1a).

✓ ***Box 1.1 Chapter 1 Volume 3 2006 IPCC Guidelines***

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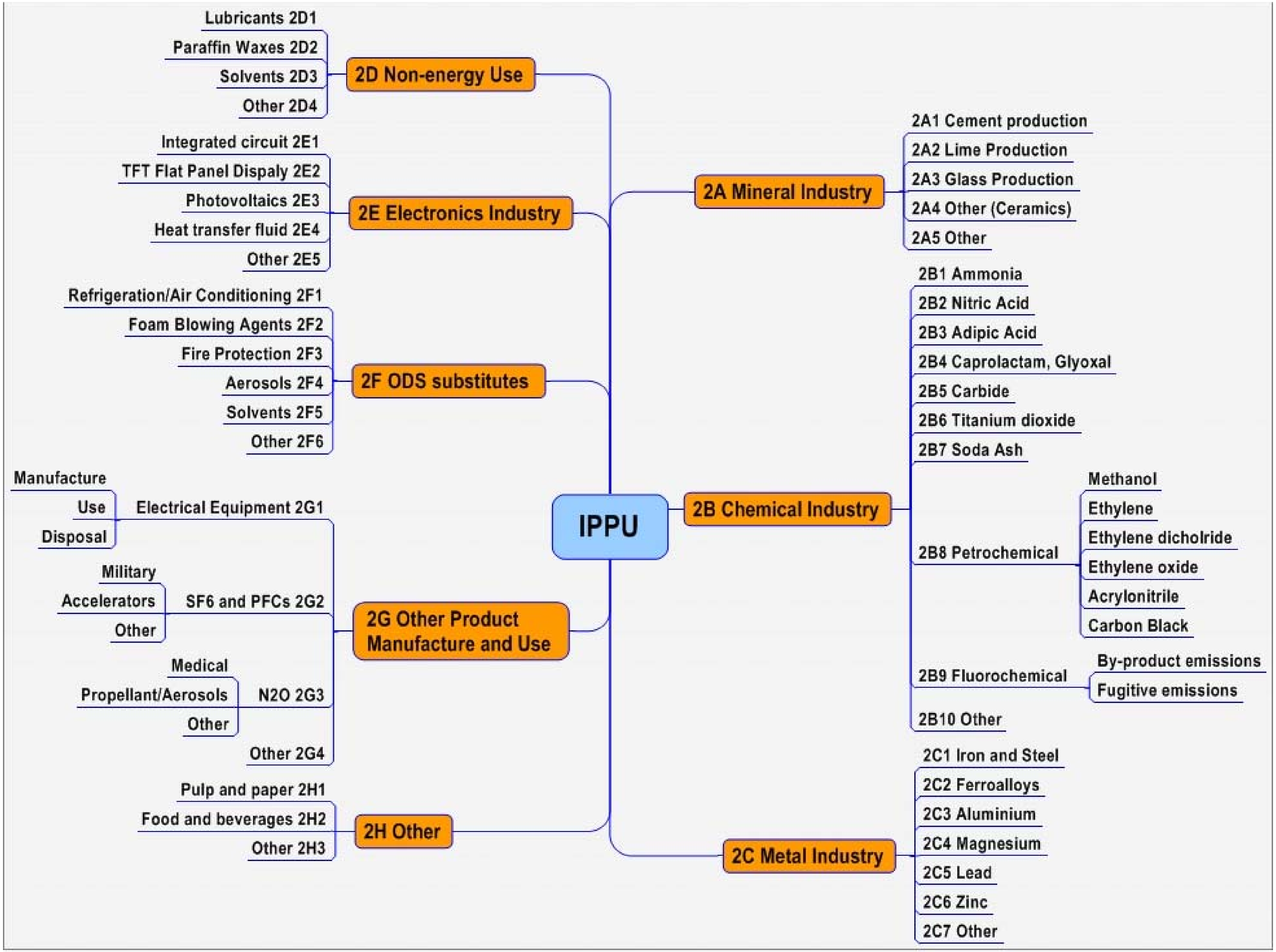
IPPU
2A Mineral Industry
2A1 Cement production
2A2 Lime Production
2A3 Glass Production
2A4 Other (Ceramics)
2A5 Other
2B Chemical Industry
2B1 Ammonia
2B2 Nitric Acid
2B3 Adipic Acid
2B4 Caprolactam, Glyoxal
2B5 Carbide
2B6 Titanium dioxide
2B7 Soda Ash
2B8 Petrochemical
Methanol
Ethylene
Ethylene dicholride
Ethylene oxide
Acrylonitrile
Carbon Black
2B9 Fluorochemical
By-product emissions
Fugitive emissions
2B10 Other
2C Metal Industry
2C1 Iron and Steel
2C2 Ferroalloys
2C3 Aluminium
2C4 Magnesium
2C5 Lead
2C6 Zinc
2C7 Other
2D Non-energy Use
Lubricants 2D1
Paraffin Waxes 2D2
Solvents 2D3
Other 2D4
2E Electronics Industry
Integrated circuit 2E1
TFT Flat Panel Dispaly 2E2
Photovoltaics 2E3
Heat transfer fluid 2E4
Other 2E5
2F ODS substitutes
Refrigeration/Air Conditioning 2F1
Foam Blowing Agents 2F2
Fire Protection 2F3
Aerosols 2F4
Solvents 2F5
Other 2F6
2G Other Product Manufacture and Use
Electrical Equipment 2G1
Manufacture
Use
Disposal
SF6 and PFCs 2G2
Military
Accelerators
Other
N2O 2G3
Medical
Propellant/Aerosols
Other
Other 2G4
2H Other
Pulp and paper 2H1
Food and beverages 2H2
Other 2H3

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	*	*	*	*	*	*	*

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	*	*	*	*	*	*	*

2 Industrial Processes and Product Use (Note 1, 2)	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Other halo-genated Gases (Note3)
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	*	*	*				

IPPU 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
    - ✓ ***Inclusion of F-gases is important because of their high global warming potential (GWP), substantial use in industrial processes and in households, significant opportunities for GHG abatement***

2A: Mineral Industry

- **Transformation of carbonate-contained compounds – limestone, dolomite, etc.** *($CaCO_3$, $MgCO_3$, Na_2CO_3)*
- **CO_2 Emissions**

Code	Category	Default EF
2A1:	**Cement Production**	0.51 t CO_2/t clinker
2A2:	**Lime Production**	0.75 t CO_2/t lime
2A3:	**Glass Production**	0.10 t CO_2/t glass
2A4:	**Other Process Uses of Carbonates**	
2A4a:	Ceramics	*Chapter 2.5*
2A4b:	Other Uses of Soda Ash	0.41 t CO_2/ t soda ash
2A4c:	Non Metallurgical Magnesia Production	0.52 t CO_2/t magnesite
2A4d:	Other	
2A5:	**Other**	

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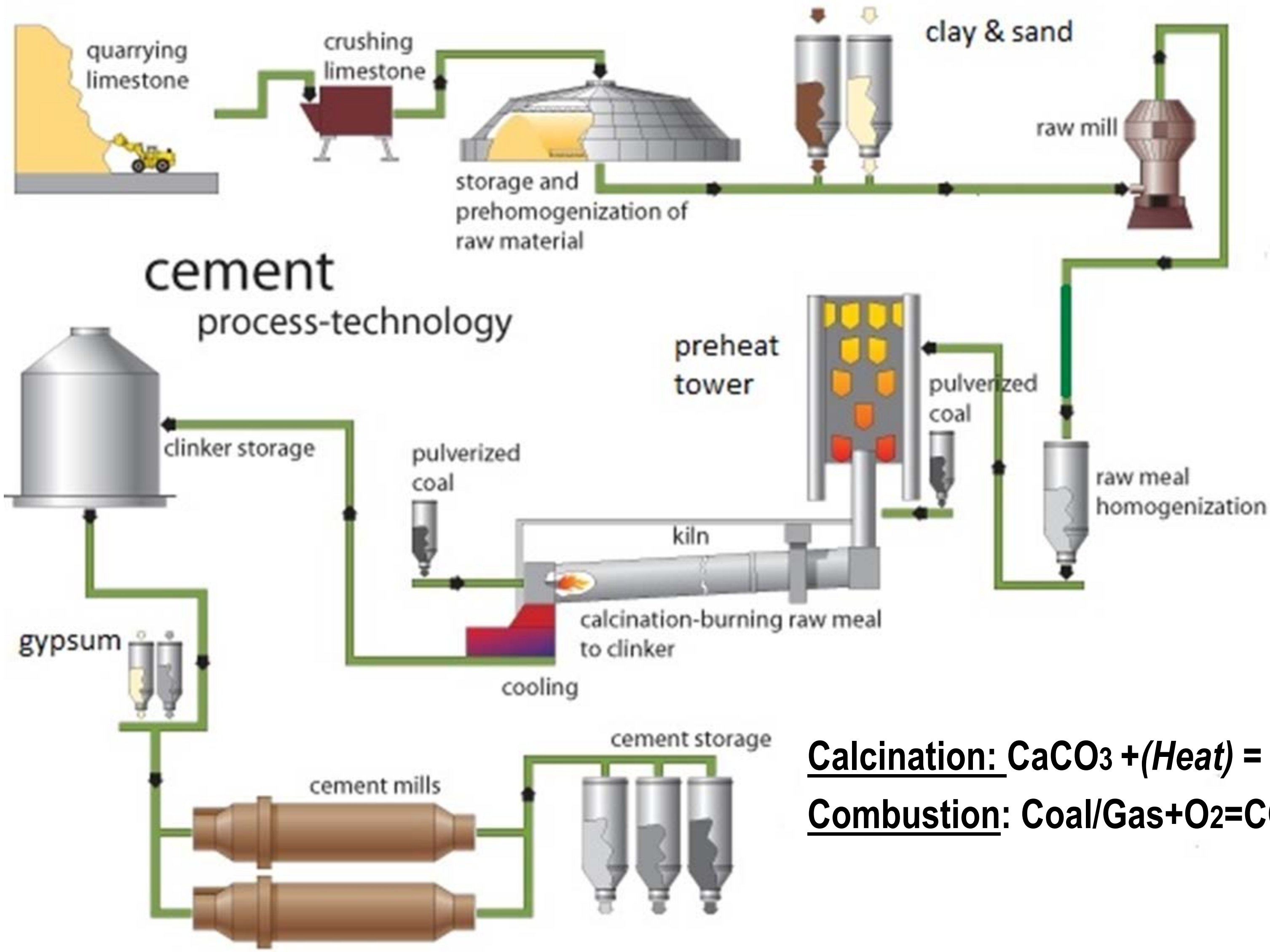
2A1: Cement production



<u>Calcination:</u> $CaCO_3$ +*(Heat)* = $CaO+CO_2$ (IPPU)

<u>Combustion</u>: Coal/Gas+O_2=CO_2 +*(Heat)* (Energy)

Image: applied from DCMAC: http://www.dscrusher.com/solutions/production-line/sand-cement-cogeneration-production-line.html *(as of March, 1 , 2015)*

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 1)

$$CO_2 \text{ Emissions} = AD_{\text{clinker production}} \times EF_{\text{clinker}}$$

$$CO_2 \text{ Emissions} = [\Sigma(M_{c,i} \times C_{Cl,i}) - Im + Ex] \times EF_{Clc}$$

$M_{c,i}$ - *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 tonnes CO_2/tonne clinker

(corrected for cement kiln dust (CKD))

CO_2 from Cement Production (Tier 2)

Tier 2 includes a correction addition for emissions associated with Cement Kiln Dust (**CKD**) not recycled to the kiln which is considered to be 'lost' and associated emissions are not accounted for by the clinker:

$$CO_2\ Emissions = M_{cl} \times EF_{cl} \times CF_{CKD}$$
$$CF_{CKD} = 1 + (M_d / M_{cl}) * C_d * F_d * (EF_c / EF_{cl})$$

CF_{CKD} - *emissions correction factor for CKD, dimensionless*
M_d - *weight of CKD not recycled to the kiln, tonnes*
M_{cl} - *weight of clinker produced, tonnes*
C_d - *fraction of original carbonate in the CKD (i.e., before calcination), fraction*
F_d - *fraction calcination of the original carbonate in the CKD, fraction*
EF_c - *emission factor for the carbonate, tonnes CO2/tonne carbonate*
EF_{cl} - *emission factor for clinker uncorrected for CKD, tonnes CO2/ tonne clinker (i.e., 0.51)*

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CO_2 from Cement Production (Tier 3)

- Limestones and shales (raw materials) also may contain a proportion of organic carbon (kerogen); other raw materials (e.g., fly ash) may contain carbon residues, which would yield <u>additional CO2</u> when burned

- Detailed plant-level data on the carbonate raw materials is needed

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

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

2B: Chemical Industry

Code	Category	Default EF		
		CO_2	N_2O	CH_4
2B1:	Ammonia Production	X		
2B2:	Nitric Acid Production		X	
2B3:	Adipic Acid Production		X	
2B4:	Caprolactam, Glyoxal and Glyoxylic Acid Production		X X X	
2B5:	Carbide Production - SiC - CaC_2	 X X		X
2B6:	Titanium Dioxide Production	X		
2B7:	Soda Ash Production	X		

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2B: Chemical Industry

Code	Category	Default EF		
		CO_2	CH_4	F-gases
2B8:	**Petrochemical and Carbon Black Production**			
2B8a:	❑ Methanol	X	X	
2B8b:	❑ Ethylene	X	X	
2B8c:	❑ Ethylene Dichloride and Vinyl Chloride Monomer	X X	X	
2B8d:	❑ Ethylene Oxide	X	X	
2B8e:	❑ Acrylonitrile	X	X	
2B8f:	❑ Carbon Black	X	X	
2B9:	**Fluorochemical Production**			
2B9a:	❑ By-product Emissions			X
2B9b:	❑ Fugitive Emissions			X

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2B1: Ammonia Production

- CO_2 **associated with urea production & use:**
  - 1996 GL: all these emissions were implicitly included in CO_2 from Ammonia Production
  - 2006 GL: CO_2 recovered in the ammonia production process for urea production should be deducted from CO_2 emissions from 2B1 Ammonia Production

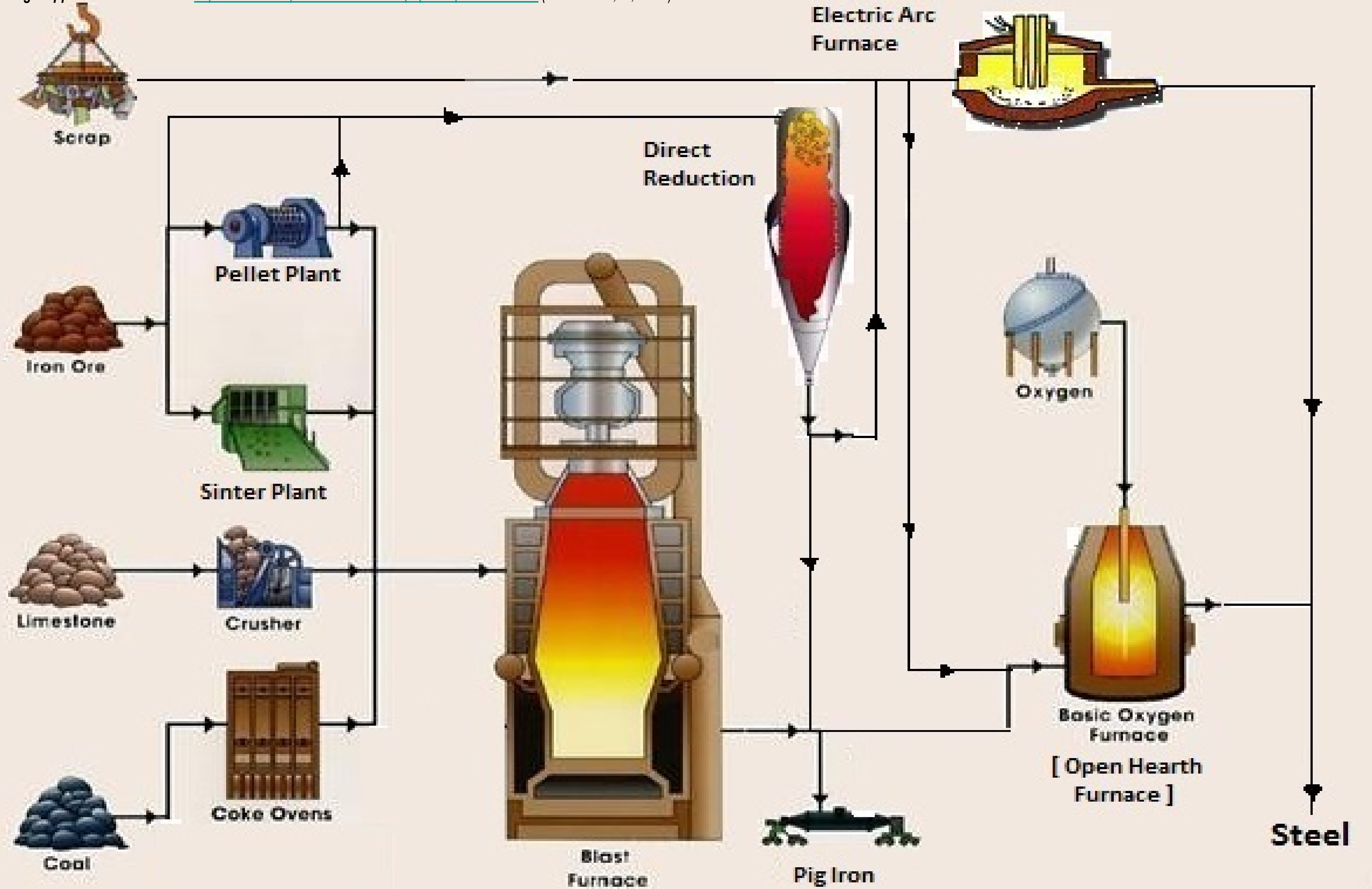
- CO_2 **emissions from urea use/incineration should be reported in the category where they occur, e.g.:**
  - Use of urea-based catalysts (Energy – Road Transport)
  - Urea application to agricultural soils (AFOLU)
  - Incineration of urea-based products (Waste)

- **Thus, now, proper account can be taken for urea produced in ammonia plants**

2C: Metal Industry

Code	Category	CO_2	CH_4	F-gases
2C1:	Iron and Steel Production	X	X	
2C2:	Ferroalloys Production	X	X	
2C3:	Aluminium Production	X		X
2C4:	Magnesium Production	X		X
2C5:	Lead Production	X		
2C6:	Zinc Production	X		
2C7:	Other			

Image: applied from MetalPass http://www.metalpass.com/metaldoc/paper.aspx?docID=251 *(as of March, 1 , 2015)*



Coke production: | **Iron Production:** + Iron Ore = Iron + Carbon Dioxide (IPPU)

Coal + (*Heat*) = Coke + Carbon Dioxide | Coke

(Energy) | **Combustion:** + Oxygen = Carbon Dioxide + (*Heat*) (IPPU)

2C1: CO_2 from Iron and Steel Production (Tier 1)

CO_2 emissions from Iron & Steel production:

$$CO_2 \text{ Emissions} = \Sigma(AD_i \times EF_i)$$

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*	Default EF	Global average default EF for Steel
	tonne CO2/tonne material *i*	
▪ Crude steel from Basic Oxygen Furnace	1.46	1.06
▪ Crude steel from Electric Arc Oxygen Furnace	0.08	
▪ Crude steel from Open Hearth Furnace	1.72	
▪ Pig iron not converted to steel	1.35	(If activity data on steel production for each process is not available, multiply total steel production by this EF)
▪ Direct reduced iron	0.70	
▪ Sinter	0.20	
▪ Pellet	0.03	

2C1: CO_2 from Iron and Steel Production (Tier 2)

CO_2 EMISSIONS FROM IRON & STEEL PRODUCTION (TIER 2)

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

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]

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2D: Non-Energy Products from Fuels and Solvent Use

- **GHG emissions from use of non-energy products (lubricants, waxes, greases, solvents) other than:**
  - combustion for energy purposes;
  - use as feedstock or reducing agent;
  - incineration of waste oils/lubricants with/without energy recovery (Energy/Waste Sector).
- **A small proportion of non-energy products oxidises during use**
- **Focus on direct CO_2 emissions and substantial NMVOC/CO emissions which eventually oxidise to CO_2 in the atmosphere**

Code	Category	CO_2	NMVOC, CO
2D1:	Lubricant Use	X	
2D2:	Paraffin Wax Use	X	
2D3:	Solvent Use		X
2D4:	Other (asphalt production and use)		X

2E: Electronics Industry

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

Gases: CF_4, C_2F_6, C_3F_8, c-C_4F_8, c-C_4F_8O, C_4F_6, C_5F_8, CHF_3, CH_2F_2, nitrogen trifluoride (NF_3), sulfur hexafluoride (SF6)

Electronics industry:

several advanced electronics manufacturing processes utilise fluorinated compounds for plasma etching silicon containing materials, cleaning reactor chambers, and temperature control. The specific electronic industries include semiconductor, thin-film-transistor flat panel display (TFT-FPD), and photovoltaic (PV) manufacturing

2F: Fluorinated Substitutes for ODS

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

2F: Fluorinated Substitutes for ODS

- ***Applications* or *Sub-applications*** - major groupings of current and expected usage of the ODS substitutes
- ***Actual emissions*** vs. ***Potential emissions*** (2006 vs.1996)
- ***Prompt emissions*** (within 2 years) **and Delayed emissions**
- ***Bank*** – total amount of substances contained in existing equipment, chemical stockpiles, foams, other products not yet released to the atmosphere (+ExIm)
- **Approaches:**
  - ✓Emission Factor (a) and Mass-balance (b)
  - ✓Tier 1 and Tier 2

Actual emissions vs. *Potential emissions*

- **The 2006 IPCC Guidelines provide with methods for estimating *actual emissions* of ODS substitutes in contrast to *potential emissions* approach (**_1996 IPCC Guidelines_**) taking into account the time lag between consumption of ODS substitutes and emissions.**

- ***Potential emissions* approach assumes that all emissions from an activity occur in the current year (**_manufacture + import - export - destruction_**), *ignoring the fact they will occur over many years, thus estimates may become very inaccurate***

Example. *A household refrigerator emits little or no refrigerant through leakage during its lifetime and most of its charge is not released until its disposal, many years after production. Even then, disposal may not entail significant emissions if the refrigerant and the blowing agent in the refrigerator are both captured for recycling or destruction*

- **Use of *actual emissions* allows to:**
  - ✓ accurately estimate emissions of ODS substitutes
  - ✓ proper address emission reductions of abatement techniques

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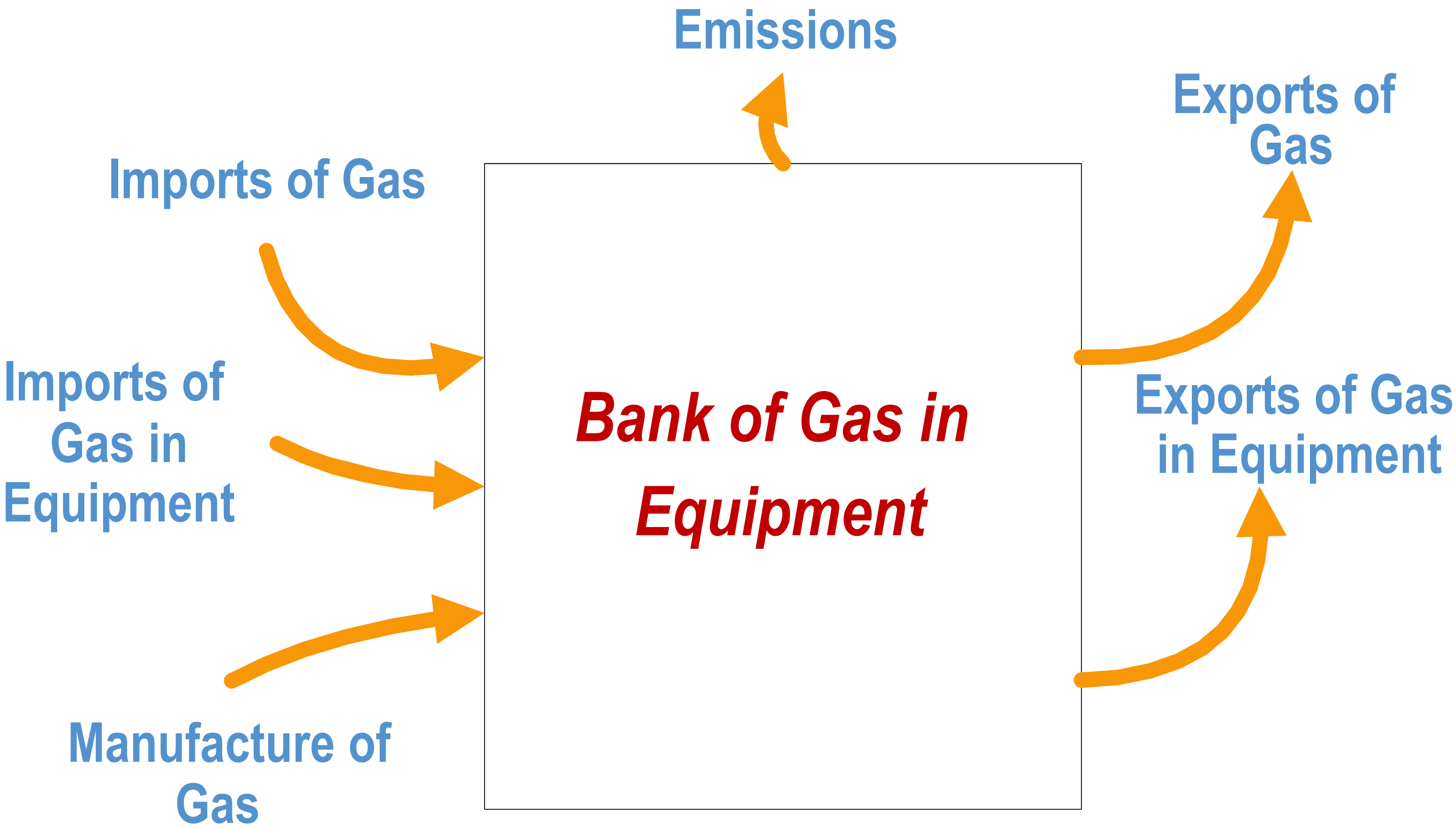
Bank


Emissions
Exports of Gas
Imports of Gas
Imports of Gas in Equipment
Bank of Gas in Equipment
Exports of Gas in Equipment
Manufacture of Gas

Bank

- **Where delays in emission occur, the cumulative difference between the chemical that has been consumed in an application and that which has already been released is known as a *bank* (***refrigeration and air conditioning, fire protection, closed-cell foams*****).**

  Example. *Blowing agent still present in foamed products which may have already been land-filled is still part of the bank, since it is chemical which has been consumed and still remains to be released.*

- **Estimating the size of a bank in an application is typically carried out by evaluating the historic consumption of a chemical and applying appropriate emission factors. It is also sometimes possible to estimate the size of bank from a detailed knowledge of the current stock of equipment or products.**

  Example. *In mobile air conditioning - the automobile statistics may be available providing information on car populations by type, age and even the presence of air conditioning. With knowledge of average charges, an estimate of the bank can be derived without a detailed knowledge of the historic chemical consumption, although this is still usually useful as a cross-check.*

..it is good practice to consider the number and relevance of sub-applications, the data availability, and the emission patterns…for rigorous emissions estimates, inventory compilers are likely to favour estimating emissions for each sub-application separately.. (Tier 2)

Chemical Consumption, Bank, or Emissions		Product Data for Application						
		Sub-Application 1			Sub-Application 2			Etc.
		Domestic Production	+ Imports	- Exports	Domestic Production	+ Imports	- Exports	
Chemical Data for Application	Chemical 1							
	Chemical 2			Complete each cell (some may be zero) using chemical and product data as available. For blends, separate data into individual chemical constituents. Determine if chemical data includes that chemical used in blends or not.				
	Chemical 3							
	Blend A							
	Blend B							
	Etc.							

2F: Sub-applications

2F Product Uses as Substitutes for Ozone Depleting Substances			
2F1	**Refrigeration and Air Conditioning**		**- Open foams**
	Domestic (i.e., household) refrigeration		PU Flexible Foam
	Commercial refrigeration including different types of equipment, from vending machines to centralised refrigeration systems in supermarkets		PU Flexible Moulded Foam
	Industrial processes including chillers, cold storage, and industrial heat pumps used in the food, petrochemical and other industries		PU Integral Skin Foam
	Transport refrigeration including equipment and systems used in refrigerated trucks, containers, reefers, and wagons		PU One Component Foam
	Mobile air-conditioning systems used in passenger cars, truck cabins, buses, and trains	**2F3**	**Fire Protection**
			Portable (streaming) equipment
			Fixed (flooding) equipment
2F2	**Foam Blowing Agents**	**2F4**	**Aerosols**
	- Closed Foams		Metered Dose Inhalers (MDIs)
	PU Continuous Panel		Personal Care Products (e.g., hair care, deodorant, shaving cream)
	PU Discontinuous Panel		Household Products (e.g., air-fresheners, oven and fabric cleaners)
	PU Appliance Foam		Industrial Products (e.g., special cleaning sprays such as those for operating electrical contact, lubricants, pipe-freezers)
	PU Injected Foam		Other General Products (e.g., silly string, tyre inflators, klaxons).
	PU Continuous Block	**2F5**	**Solvents**
	PU Discontinuous Block		Precision Cleaning
	PU Continuous Laminate		Electronics Cleaning
	PU Spray Foam		Metal Cleaning
	PU Pipe-in-Pipe		Deposition applications
	Extruded Polystyrene	**2F6**	**Other Applications**
	Phenolic Block		
	Phenolic Laminate	**TOTAL: 32 sub-applications**	

2F: Chemicals and blends

Chemical	Refrigeration and Air Conditioning	Fire Suppression and Explosion Protection	Aerosols		Solvent Cleaning	Foam Blowing	Other Applications
			Propellants	Solvents			
HFC-23	X	X					
HFC-32	X						
HFC-125	X	X					
HFC-134a	X	X	X			X	X
HFC-143a	X						
HFC-152a	X		X			X	
HFC-227ea	X	X	X			X	X
HFC-236fa	X	X					
HFC-245fa				X		X	
HFC-365mfc				X	X	X	
HFC-43-10mee				X	X		
PFC-14 (CF4)		X					
PFC-116 (C2F6)							X
PFC-218 (C3F8)							
PFC-31-10 (C4F10)		X					
PFC-51-14 (C6F14)					X		
BLENDS							

2F: Blends

Blend	Constituents	Composition (%)
R-400	CFC-12/CFC-114	Should be specified[1]
R-401A	HCFC-22/HFC-152a/HCFC-124	(53.0/13.0/34.0)
R-401B	HCFC-22/HFC-152a/HCFC-124	(61.0/11.0/28.0)
R-401C	HCFC-22/HFC-152a/HCFC-124	(33.0/15.0/52.0)
R-402A	HFC-125/HC-290/HCFC-22	(60.0/2.0/38.0)
R-402B	HFC-125/HC-290/HCFC-22	(38.0/2.0/60.0)
R-403A	HC-290/HCFC-22/PFC-218	(5.0/75.0/20.0)
R-403B	HC-290/HCFC-22/PFC-218	(5.0/56.0/39.0)
R-404A	HFC-125/HFC-143a/HFC-134a	(44.0/52.0/4.0)
R-405A	HCFC-22/ HFC-152a/ HCFC-142b/PFC-318	(45.0/7.0/5.5/42.5)
R-406A	HCFC-22/HC-600a/HCFC-142b	(55.0/14.0/41.0)
R-407A	HFC-32/HFC-125/HFC-134a	(20.0/40.0/40.0)
R-407B	HFC-32/HFC-125/HFC-134a	(10.0/70.0/20.0)
R-407C	HFC-32/HFC-125/HFC-134a	(23.0/25.0/52.0)
R-407D	HFC-32/HFC-125/HFC-134a	(15.0/15.0/70.0)
R-407E	HFC-32/HFC-125/HFC-134a	(25.0/15.0/60.0)
R-408A	HFC-125/HFC-143a/HCFC-22	(7.0/46.0/47.0)
R-409A	HCFC-22/HCFC-124/HCFC-142b	(60.0/25.0/15.0)
R-409B	HCFC-22/HCFC-124/HCFC-142b	(65.0/25.0/10.0)
R-410A	HFC-32/HFC-125	(50.0/50.0)
R-410B	HFC-32/HFC-125	(45.0/55.0)
R-411A	HC-1270/HCFC-22/HFC-152a	(1.5/87.5/11.0)
R-411B	HC-1270/HCFC-22/HFC-152a	(3.0/94.0/3.0)
R-411C	HC-1270/HCFC-22/HFC-152a	(3.0/95.5/1.5)
R-412A	HCFC-22/PFC-218/HCFC-142b	(70.0/5.0/25.0)
R-413A	PFC-218/HFC-134a/HC-600a	(9.0/88.0/3.0)
R-414A	HCFC-22/HCFC-124/HC-600a/HCFC-142b	(51.0/28.5/4.0/16.5)
R-414B	HCFC-22/HCFC-124/HC-600a/HCFC-142b	(50.0/39.0/1.5/9.5)
R-415A	HCFC-22/HFC-152a	(82.0/18.0)
R-415B	HCFC-22/HFC-152a	(25.0/75.0)
R-416A	HFC-134a/HCFC-124/HC-600	(59.0/39.5/1.5)
R-417A	HFC-125/HFC-134a/HC-600	(46.6/50.0/3.4)
R-418A	HC-290/HCFC-22/HFC-152a	(1.5/96.0/2.5)
R-419A	HFC-125/HFC-134a/HE-E170	(77.0/19.0/4.0)
R-420A	HFC-134a/HCFC-142b	(88.0/12.0)
R-421A	HFC-125/HFC-134a	(58.0/42.0)
R-421B	HFC-125/HFC-134a	(85.0/15.0)
R-422A	HFC-125/HFC-134a/HC-600a	(85.1/11.5/3.4)
R-422B	HFC-125/HFC-134a/HC-600a	(55.0/42.0/3.0)
R-422C	HFC-125/HFC-134a/HC-600a	(82.0/15.0/3.0)
R-500	CFC-12/HFC-152a	(73.8/26.2)
R-501	HCFC-22/CFC-12	(75.0/25.0)
R-502	HCFC-22/CFC-115	(48.8/51.2)
R-503	HFC-23/CFC-13	(40.1/59.9)
R-504	HFC-32/CFC-115	(48.2/51.8)
R-505	CFC-12/HCFC-31	(78.0/22.0)
R-506	CFC-31/CFC-114	(55.1/44.9)
R-507A	HFC-125/HFC-143a	(50.0/50.0)
R-508A	HFC-23/PFC-116	(39.0/61.0)
R-508B	HFC-23/PFC-116	(46.0/54.0)
R-509A	HCFC-22/PFC-218	(44.0/56.0)

2F: Tiers / Approaches and Data

	Approach A (emission-factor approach)	Approach B (mass-balance approach)
Tier 2 (emission estimation at a **disaggregated** level)	· Data on chemical sales and usage pattern by sub-application · Emission factors by sub-application	· Data on chemical sales by sub-application · Data on historic and current equipment sales adjusted for import/export by sub-application
Tier 1 (emission estimation at an **aggregated** level)	· Data on chemical sales by application · Emission factors by application	· Data on chemical sales by application · Data on historic and current equipment sales adjusted for import/export by application

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2F4 / 2F5: Solvents / Aerosols

For prompt emissions *(solvents, aerosols):*

$$\text{GHG Emissions} = S_t * EF + S_{t-1} * (1 - EF)$$

S *– quantity of chemical sales in current and previous year t, t-1*

EF *= 1 for two years (100%), default EF - 0.5/0.5*

2F2: Foams Blowing Agents

- **Open foams** *(GHG immediate release):*

$$\boxed{\text{GHG Emissions} = M_t}$$

M_t - *total HFC used in manufacturing new open-cell foam in year t, tonnes*

- **Closed foams** *(GHG delayed release):*

$$\boxed{\text{GHG Emissions} = M_t{*}EF_{FYL} + Bank_t{*}EF_{AL} + DL_t - RD_t}$$

M_t - *total HFC used in manufacturing new closed-cell foam in year t*
EF_{FYL} - *first year loss emission factor*
$Bank_t$ - *HFC charge blown into closed-cell foam manufacturing between year t and year t-n*
EF_{AL} - *annual loss emission factor*
DL_t - *decommissioning losses or remaining losses of chemical at the end of*
RD_t - *HFC emissions prevented by recovery and destruction*

2F2: Closed foams: Emission Factors

TABLE 7.7
DEFAULT EMISSION FACTORS FOR HFC-245fa/HFC-365mfc/HFC-227ea USES (FOAM SUB-APPLICATION)

HFC-245a/HFC-365mfc Applications	Product Life in years	First Year Loss %	Annual Loss %	Maximum Potential End-of-Life Loss %
Polyurethane – Continuous Panel	50	5	0.5	70
Polyurethane – Discontinuous Panel	50	12	0.5	63
Polyurethane – Appliance	15	4	0.25	92.25
Polyurethane – Injected	15	10	0.5	82.5
Polyurethane – Cont. Block	15	20	1	65
Polyurethane – Disc. Block for pipe sections	15	45	0.75	43.75
Polyurethane – Disc. Block for panels	50	15	0.5	60
Polyurethane – Cont. Laminate / Boardstock	25	6	1	69
Polyurethane – Spray	50	15	1.5	10
Polyurethane – Pipe-in-Pipe	50	6	0.25	81.5
Phenolic – Discontinuous Block	15	45	0.75	43.75
Phenolic – Discontinuous Laminate	50	10	1	40
Polyurethane – Integral Skin	12	95	2.5	0

Source: Ashford and Jeffs (2004) assembled from UNEP FTOC Reports (UNEP-FTOC, 1999; UNEP-FTOC, 2003)

2F1: Refrigeration/Air Conditioning

Tier 2b *(Mass-Balance):*

Emissions = Annual Sales of New Refrigerant – Total Charge of New Equipment+ + Original Total Charge of Retiring Equipment - Amount of Intentional Destruction

✓ *in estimating Annual Sales of New Refrigerant, Total Charge of New Equipment, and Original Total Charge of Retiring Equipment, inventory compilers should account for imports and exports of both chemicals and equipment.*

Tier 2a *(Emission factor):*

$$\text{Emissions} = E_{containers} + E_{charge} + E_{lifetime} + E_{end\text{-}of\text{-}life}$$

- $E_{containers} = RM * c/100$
- $E_{charge} = M * k/100$
- $E_{lifetime} = B * x/100$
- $E_{end\text{-}of\text{-}life} = M * p/100 * (1 - n/100)$

EFs: c, k, x, p, n

2F1: Refrigeration/AC: Emission Factors

Table 7.9 Estimates[1] for charge, lifetime and emission factors for refrigeration and air-conditioning systems						
Sub-application	**Charge (kg)**	**Lifetimes (years)[2]**	**Emission Factors (% of initial charge/year)[3]**		**End-of-Life Emission (%)**	
Factor in Equation	**(M)**	**(d)**	**(k)**	**(x)**	**($\eta_{rec,d}$)**	**(p)**
			Initial Emission	**Operation Emission**	**Recovery Efficiency[4]**	**Initial Charge Remaining**
Domestic Refrigeration	$0.05 \leq M \leq 0.5$	$12 \leq d \leq 20$	$0.2 \leq k \leq 1$	$0.1 \leq x \leq 0.5$	$0 < \eta_{rec,d} < 70$	$0 < p < 80$
Stand-alone Commercial Applications	$0.2 \leq M \leq 6$	$10 \leq d \leq 15$	$0.5 \leq k \leq 3$	$1 \leq x \leq 15$	$0 < \eta_{rec,d} < 70$	$0 < p < 80$
Medium & Large Commercial Refrigeration	$50 \leq M \leq 2000$	$7 \leq d \leq 15$	$0.5 \leq k \leq 3$	$10 \leq x \leq 35$	$0 < \eta_{rec,d} < 70$	$50 < p < 100$
Transport Refrigeration	$3 \leq M \leq 8$	$6 \leq d \leq 9$	$0.2 \leq k \leq 1$	$15 \leq x \leq 50$	$0 < \eta_{rec,d} < 70$	$0 < p < 50$
Industrial Refrigeration including Food Processing and Cold Storage	$10 \leq M \leq 10{,}000$	$15 \leq d \leq 30$	$0.5 \leq k \leq 3$	$7 \leq x \leq 25$	$0 < \eta_{rec,d} < 90$	$50 < p < 100$
Chillers	$10 \leq M \leq 2000$	$15 \leq d \leq 30$	$0.2 \leq k \leq 1$	$2 \leq x \leq 15$	$0 < \eta_{rec,d} < 95$	$80 < p < 100$
Residential and Commercial A/C, including Heat Pumps	$0.5 \leq M \leq 100$	$10 \leq d \leq 20$	$0.2 \leq k \leq 1$	$1 \leq x \leq 10$	$0 < \eta_{rec,d} < 80$	$0 < p < 80$
Mobile A/C	$0.5 \leq M \leq 1.5$	$9 \leq d \leq 16$	$0.2 \leq k \leq 0.5$	$10 \leq x \leq 20$[5]	$0 < \eta_{rec,d} < 50$	$0 < p < 50$

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Need help?

No worries!

The IPCC Software will work out!

The IPCC Inventory Software enables you to estimate actual emissions even if you do not have historic data.

(!) But you need to have the data on:

- Year of introduction of chemical
- Domestic production of chemical in current year
- Imports of chemical in current year
- Exports of chemical in current year
- Growth rate of sales of equipment that uses the chemical

Tier 1 Refrigeration
Argentina - HFC-143a

HFC-143a

Current Year	2005

Use in current year - 2005 (tonnes)	**Data Used Here**
Production of HFC-143a	800
Imports in current Year	200
Exports in current year	0
Total new agent to domestic market	*1000*

Year of Introduction of HFC-143a	1998
Growth Rate in New Equipment Sales	3.0%

Tier 1 Defaults	
Assumed Equipment Lifetime (years)	15
Emission Factor from installed base	15%
% of HFC-143a destroyed at End-of-Life	0%

In this hypothetical example, the production of a specific refrigerant (HFC-143a) are 800 tonnes with an additional 200 tonnes in imported equipment, in 2005 making a total consumption of 1 000 tonnes.

Based on the consumption pattern and knowledge of the year of introduction of the refrigerant (1998), it can be estimated that emissions will be 461 tonnes assuming the development of banks over the previous seven years.

The bank in 2005 is estimated at 3 071 tonnes.

Estimated data for earlier years	1996	1997	1998	1999	2000	2001	2002	2003	2004	**2005**
Production	0	0	81	167	259	355	458	566	680	**800**
Agent in Exports	0	0	0	0	0	0	0	0	0	**0**
Agent in Imports	0	0	20	42	65	89	114	141	170	**200**
Total New Agent in Domestic Equipment	0	0	102	209	323	444	572	707	850	**1000**
Agent in Retired Equipment	0	0	0	0	0	0	0	0	0	**0**
Destruction of agent in retired equipment	0	0	0	0	0	0	0	0	0	**0**
Release of agent from retired equipment	0	0	0	0	0	0	0	0	0	**0**
Bank	0	0	102	296	575	933	1365	1867	2437	**3071**
Emission	0	0	15	44	86	140	205	280	365	**461**

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2G: Other Product Manufacture and Use

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
2G2	SF_6/PFCs from Other Uses	2G3c	Other
2G2a	Military Applications	2G4	Other
2G2b	Accelerators		

- **SF6 and PFCs: electrical equipment:** gas insulated switchgear and substations (GIS), gas circuit breakers (GCB), high voltage gas-insulated lines (GIL), gas-insulated power transformers (GIT). **Military equipment:** ground and airborne radar, avionics, missile guidance systems, ECM (Electronic Counter Measures), sonar, amphibious assault vehicles, other surveillance aircraft, lasers, SDI (Strategic Defense Initiative), stealth aircraft. PFCs for cooling electric motors, e.g., in ships and submarines. **Cosmetic and medical applications, research particle accelerators.**
- **N2O: Medical applications, Auto-racing, Propellant in aerosol products**

IPPU Data and Cross-Checks

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').

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Data and Cross-checks / QC

- The CO_2 completeness check
- Feedstock balance check
- Potential emissions approach for estimating HFCs, PFCs, or SF_6

IPPU Data: Refrigeration/Air Conditioning

Where to get:

- Regulation for phase-out of CFCs and HCFCs
- Government Statistics
- Refrigerant Manufacturers and Distributors
- Disposal Companies
- Import/Export Companies
- Manufacturer Association
- Marketing Studies

What to get:

- schedule of phase out for charging of brand new equipment and for servicing
- number of equipment disposed of for each type of application
- all virgin refrigerants sold for charging new equipment and for servicing in the different sectors
- equipment produced on a national level using HFC refrigerants (for all sub-applications)
- number of equipment using HFCs (imported and exported)
- HFC refrigerants recovered for re-processing or for destruction
- average equipment lifetime
- initial charge of systems

IPPU Data: Confidentiality

- **Data providers might restrict access to information because it is confidential, unpublished, or not yet finalized**

- **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

Conclusion

- **Diversity of sources and gases in the IPPU Sector**
  - Difficult to exhaustively include all sources & gases
  - At least major sources & gases *(key categories)* must be included

- **Care to Activity Data:**
  - Difficult to collect activity data *(input/output data, plant-specific data)*
  - Data allocation and Double-counting
  - Confidential data from private companies

- **Various opportunities for GHG abatement**
  - Capture and abatement at plants *(N_2O destruction at nitric acid production plants)*
  - Recovery at the end of product's life and subject to either recycled or destroyed *(HFCs in refrigerators)*

Thank you for your time and attention!

Any questions?

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