Industrial Processes and Product Use (IPPU)

Remote Training on the IPCC Inventory Software for National Greenhouse Gas Inventories for the Asia-Pacific and Eastern Europe Regions

9-13 May 2022

Pavel Shermanau

IPCC TFI TSU

INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

IPPU Sector

IPPU – GHG emissions:

1. Industrial Processes
2. Product Use

1. Industrial Processes.

Chemical or physical transformation of materials releasing GHGs

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

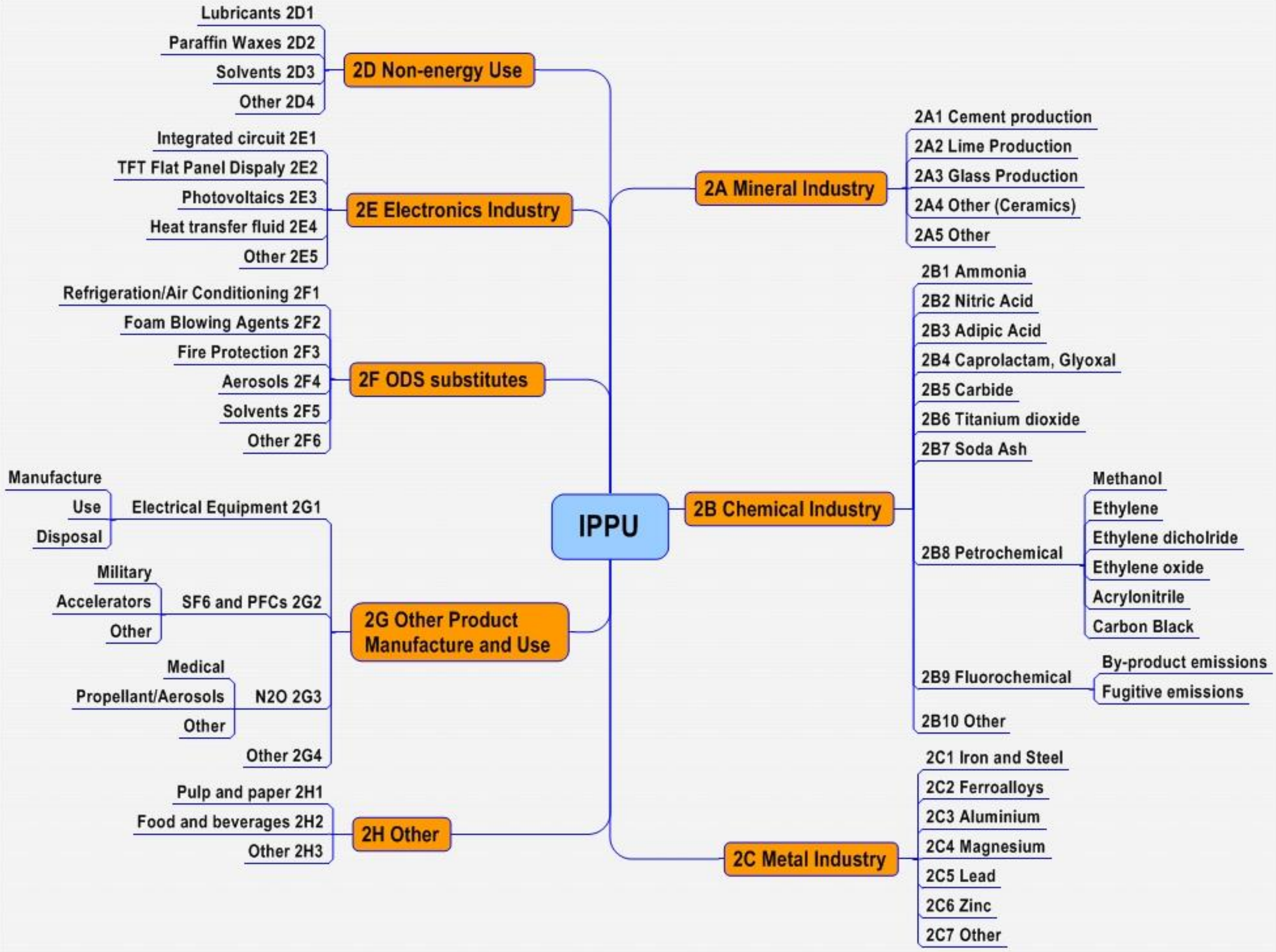
2. Product Use.

GHGs are used in products such as refrigerators, foams or aerosol cans

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**

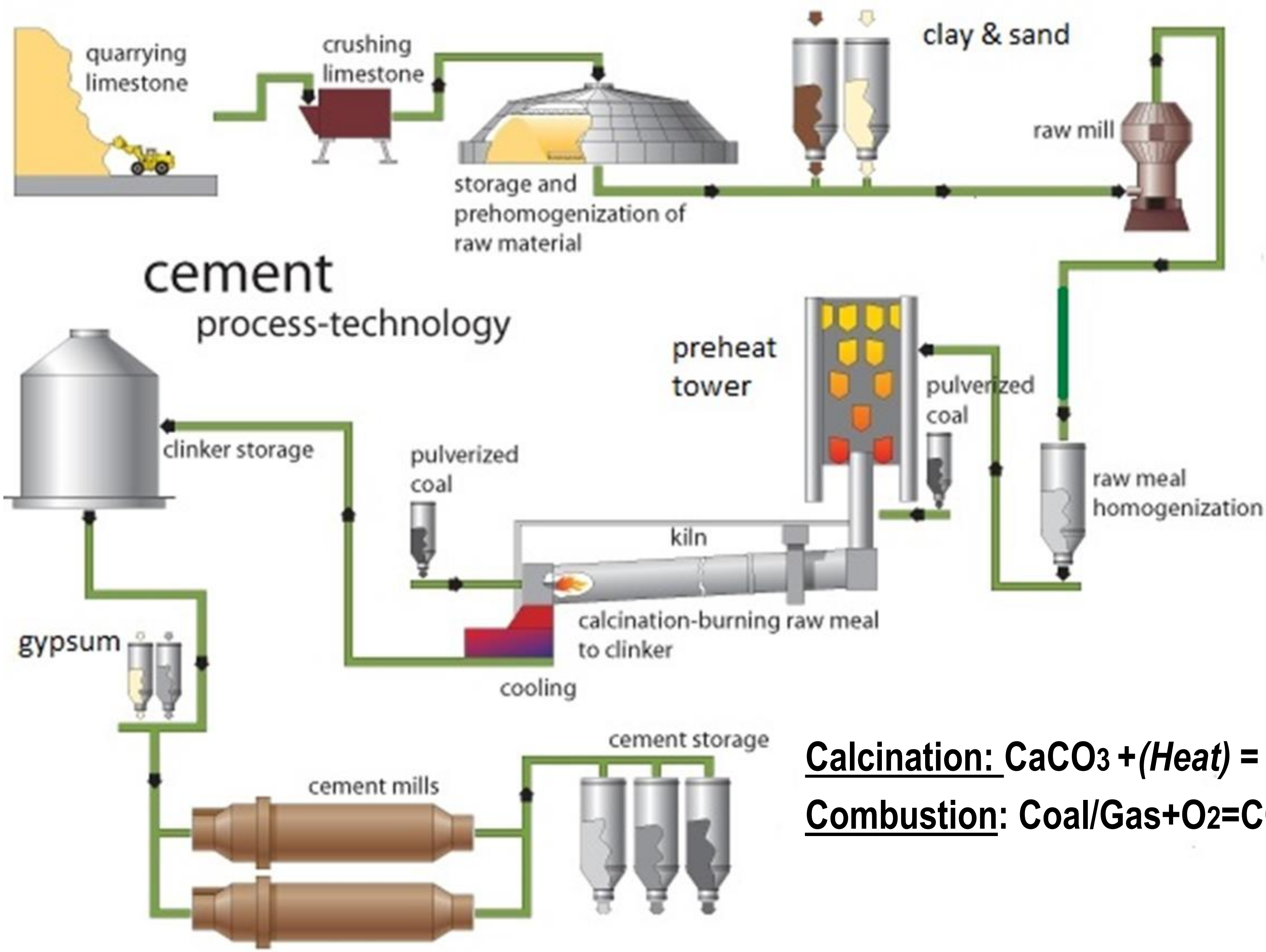

IPPU
2A Mineral Industry
2A1 Cement production
2A2 Lime Production
2A3 Glass Production
2A4 Other (Ceramics)
2A5 Other
2B Chemical Industry
2B1 Ammonia
2B2 Nitric Acid
2B3 Adipic Acid
2B4 Caprolactam, Glyoxal
2B5 Carbide
2B6 Titanium dioxide
2B7 Soda Ash
2B8 Petrochemical
Methanol
Ethylene
Ethylene dicholride
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

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**	0.52 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**	

2A1: Cement production



Calcination: $CaCO_3$ + *(Heat)* = $CaO + CO_2$ (IPPU)

Combustion: 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)

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

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

$M_{c,i}$ - *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 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)

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)*

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		

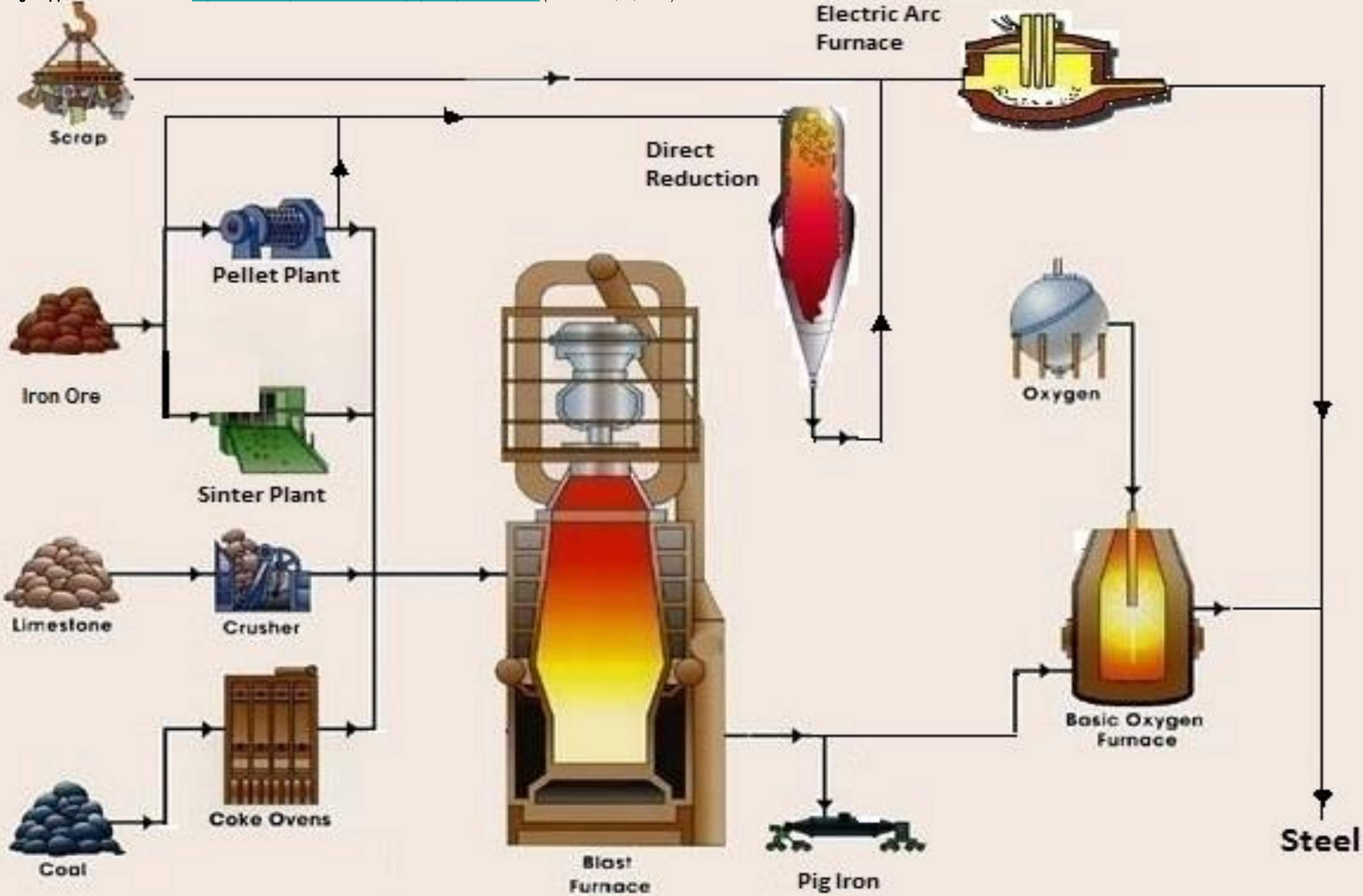
2B: Chemical Industry

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

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: (Energy)

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

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

Combustion: Coke + 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	

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

- **GHG emissions from <u>use</u> 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

WMO UNEP

ipcc INTERGOVERNMENTAL PANEL ON climate change

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

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**	

WMO UNEP

ipcc
INTERGOVERNMENTAL PANEL ON climate change

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							

WMO UNEP

INTERGOVERNMENTAL PANEL ON climate change

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)

Actual emissions vs. *Potential emissions*

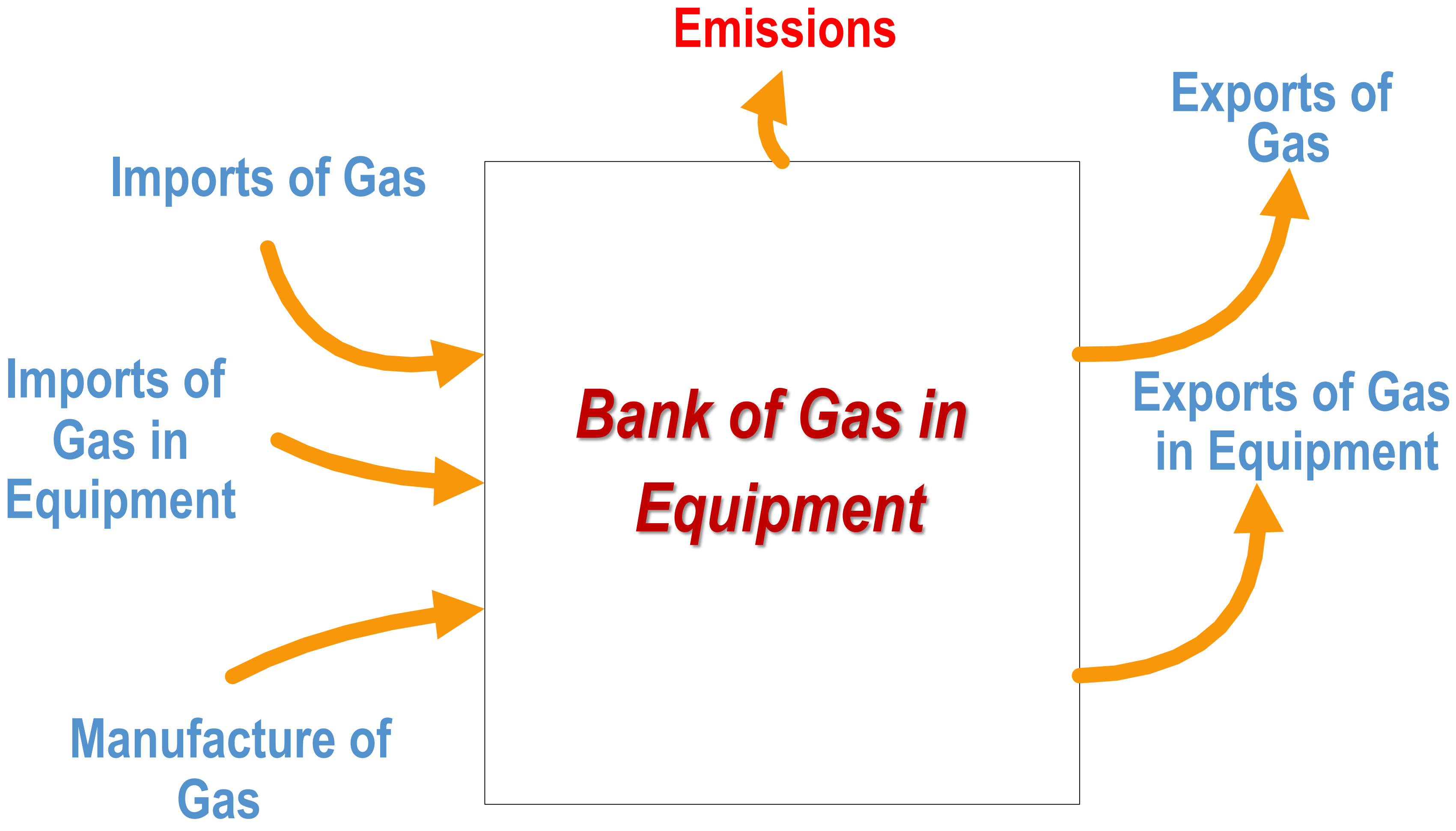
- **The 2006 IPCC Guidelines provide with methods for estimating *actual emissions* of ODS substitutes in contrast to *potential emissions* approach (***1996 IPCC Guidelines***) taking into account the time lag between consumption of ODS substitutes and emissions.**

- ***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

Estimating Bank and Emissions



Estimating Emissions (2F1, 2F2, 2F3)

- **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, closed-cell foams, fire protection_**).**

- **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.*

Estimating Emissions (2F1, 2F2, 2F3)

- **The Tier 1 method calculates back the development of a bank of a refrigerant from the current reporting year to the year of its introduction. The 2006 IPCC Guidelines contain the MS Excel spreadsheet for such estimation, and it is implemented in the IPCC Inventory Software**

- **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%

Example. *In Country X the production of a specific refrigerant (HFC-143a) is 800 tonnes with an additional 200 tonnes in imported equipment, making a total consumption of 1 000 tonnes in 2005.*

Based on the consumption figure 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**

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		

- **SF_6 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.**
- **N_2O: Medical applications, Auto-racing, Propellant in aerosol products**

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

https://www.ipcc-nggip.iges.or.jp/index.html

ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP