



Industrial Processes and Product Use (IPPU)

From the IPCC Guidelines to the IPCC Inventory Software:
F-gases and example of data input for 2F1 Refrigeration and Air conditioning

Pavel Shermanau
IPCC TFI TSU

PNG ToT Seminar – 7-11 October 2024

INTERGOVERNMENTAL PANEL ON climate change

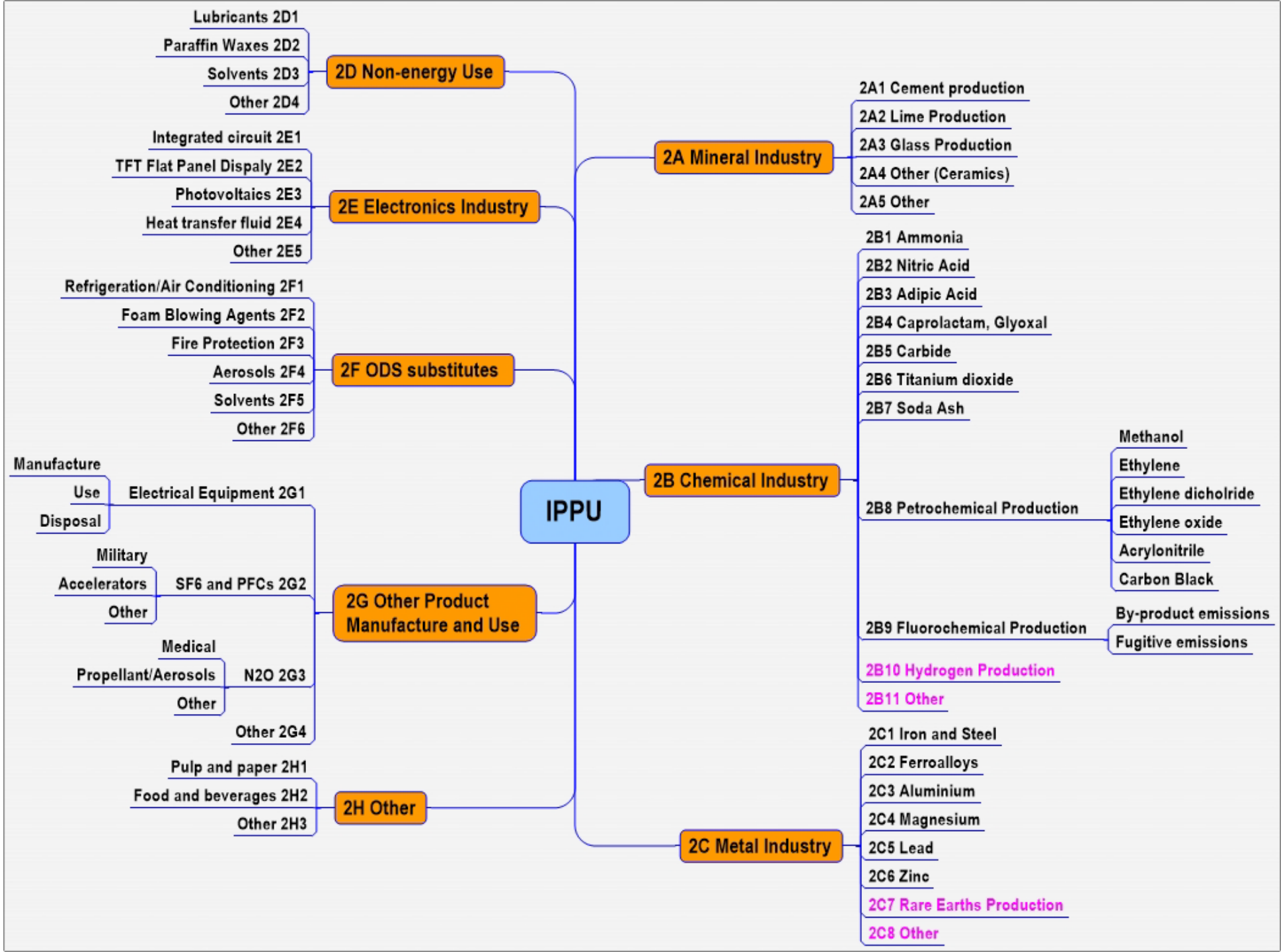
WMO UN environment programme

Introduction

- The IPCC Inventory Software implements the ***2006 IPCC Guidelines***

- There are elements of the ***2019 Refinement*** to meet the UNFCCC reporting requirements *(in magenta colour)*

IPPU

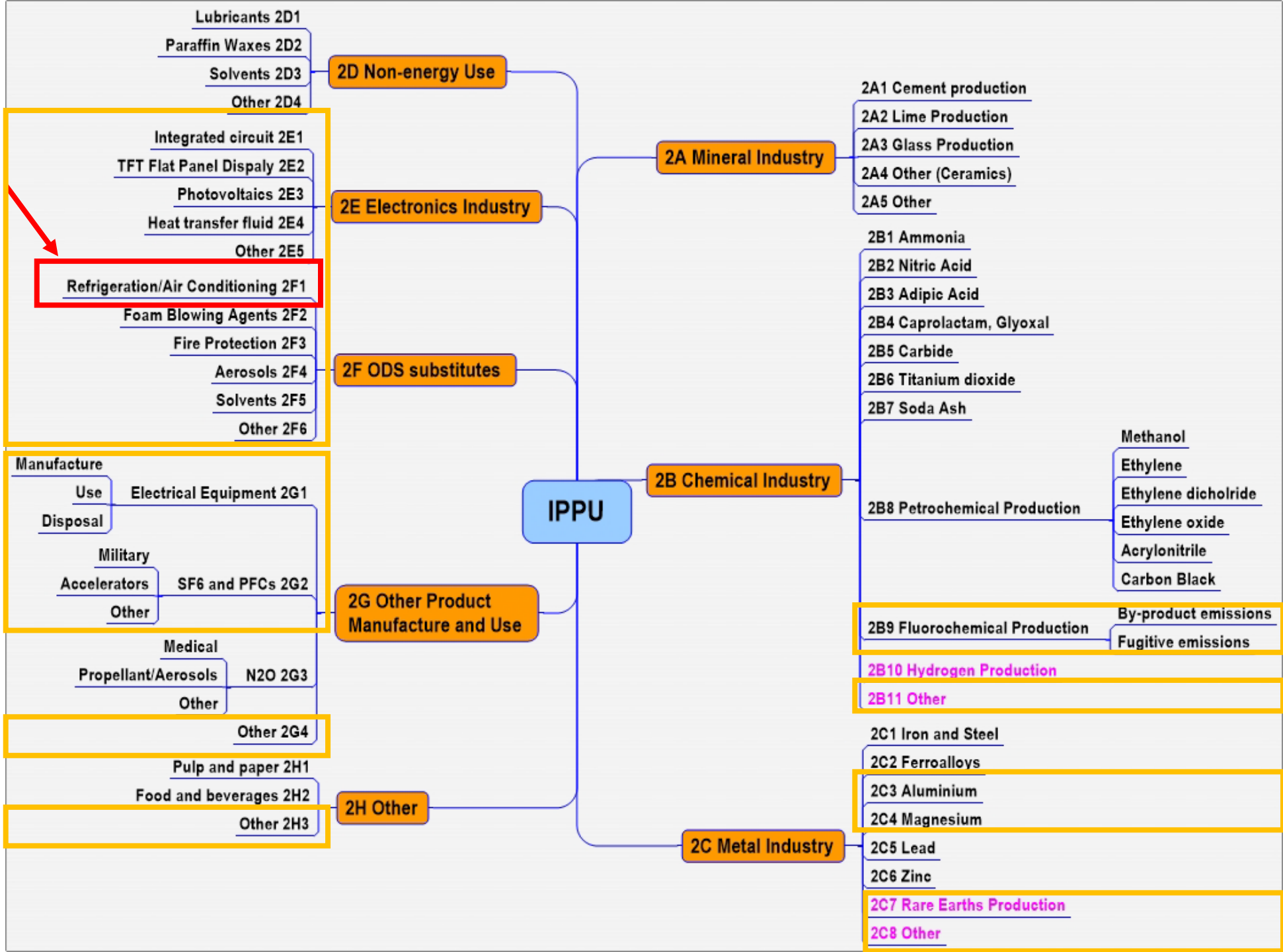

IPPU
2A Mineral Industry
2A1 Cement production
2A2 Lime Production
2A3 Glass Production
2A4 Other (Ceramics)
2A5 Other
2B Chemical Industry
2B1 Ammonia
2B2 Nitric Acid
2B3 Adipic Acid
2B4 Caprolactam, Glyoxal
2B5 Carbide
2B6 Titanium dioxide
2B7 Soda Ash
2B8 Petrochemical Production
Methanol
Ethylene
Ethylene dicholride
Ethylene oxide
Acrylonitrile
Carbon Black
2B9 Fluorochemical Production
By-product emissions
Fugitive emissions
2B10 Hydrogen Production
2B11 Other
2C Metal Industry
2C1 Iron and Steel
2C2 Ferroalloys
2C3 Aluminium
2C4 Magnesium
2C5 Lead
2C6 Zinc
2C7 Rare Earths Production
2C8 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
Manufacture
Use
Disposal
Electrical Equipment 2G1
Military
Accelerators
Other
SF6 and PFCs 2G2
Medical
Propellant/Aerosols
Other
N2O 2G3
Other 2G4
2H Other
Pulp and paper 2H1
Food and beverages 2H2
Other 2H3

F-gases

IPPU

All categories where F-gases may be produced or consumed

Presentation focuses on entering data for Refrigeration and Air Conditioning



F-gases and Blends

Most common highlighted in 2006 IPCC Guidelines

TABLE 7.1
MAIN APPLICATION AREAS FOR HFCS AND PFCS AS ODS SUBSTITUTES [1]

Chemical	Refrigeration and Air Conditioning	Fire Suppression and Explosion Protection	Aerosols		Solvent Cleaning	Foam Blowing	Other Applications[2]
			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[3] (CF_4)		X					
PFC-116 (C_2F_6)							X
PFC-218 (C_3F_8)							
PFC-31-10 (C_4F_{10})		X					
PFC-51-14[4] (C_6F_{14})					X		

TABLE 7.8
BLENDS (MANY CONTAINING HFCS AND/OR PFCS)

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)

[1] R-400 can have various proportions of CFC-12 and CFC-114. The exact composition needs to be specified, e.g., R-400 (60/40).

F-gases for UNFCCC Reporting

TABLE 2(II) SECTORAL REPORT FOR INDUSTRIAL PROCESSES AND PRODUCT USE - EMISSIONS OF HFCs, PFCs, SF_6 AND NF_3 Year

(Sheet 1 of 1) Submission

Country

Back to Index

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	HFC-23	HFC-32	HFC-41	HFC-43-10mee	HFC-125	HFC-134	HFC-134a	HFC-143	HFC-143a	HFC-152	HFC-152a	HFC-161	HFC-227ea	HFC-236cb	HFC-236ea	HFC-236fa	HFC-245ca	HFC-245fa	HFC-365mfc	Unspecified mix of HFCs (1)	Total HFCs	CF_4	C_2F_6	C_3F_8	C_4F_{10}	c-C_4F_8	C_5F_{12}	C_6F_{14}	$C_{10}F_{18}$	c-C_3F_6	Unspecified mix of PFCs (1)	Total PFCs	Unspecified mix of HFCs and PFCs (1)	SF_6	NF_3
	(t)																			CO_2 equivalents (kt) (2)		(t)									CO_2 equivalents (kt) (2)			(t)	
2. Total actual emissions of halocarbons (by chemical), SF_6 and NF_3																																		
2.B. Chemical industry																																		
2.B.9. Fluorochemical production																																		
2.B.9.a. By-product emissions																																		
2.B.9.b. Fugitive emissions																																		
2.B.10. Other																																		
2.C. Metal industry																																		
2.C.3. Aluminium production																																		
2.C.4. Magnesium production																																		
2.C.7. Other																																		
2.E. Electronics industry																																		
2.E.1. Integrated circuit or semiconductor																																		

Specific HFCs

Unspecified Mix of HFCs

Unspecified Mix of HFCs and PFCs

F-gases and Blends

Complete list in AR5

- Software calculates emissions from all F-gases in the AR5.
- For UNFCCC Reporting:
  - If the F-gas appears in CRT 2(II): the corresponding gas maps to that gas in background and sectoral tables.
  - If the F-gas does not appear in CRT 2(II): the corresponding gas maps to the "Unspecified mix", as shown in the table.

HFCs	
HFC-23 (CHF_3)	HFC-23
HFC-32 (CH_2F_2)	HFC-32
HFC-41 (CH_3F)	HFC-41
HFC-43-10mee ($CF_3CHFCHFCF_2CF_3$)	HFC-43-10mee
HFC-125 (CHF_2CF_3)	HFC-125
HFC-134 (CHF_2CHF_2)	HFC-134
HFC-134a (CH_2FCF_3)	HFC-134a
HFC-143 (CH_2FCHF_2)	HFC-143
HFC-143a (CH_3CF_3)	HFC-143a
HFC-152 (CH_2FCH_2F)	HFC-152
HFC-152a (CH_3CHF_2)	HFC-152a
HFC-161 (CH_3CH_2F)	HFC-161
HFC-227ca ($CF_3CF_2CHF_2$)	Unspecified mix of HFCs
HFC-227ea (CF_3CHFCF_3)	HFC-227ea
HFC-236cb ($CH_2FCF_2CF_3$)	HFC-236cb
HFC-236ea (CHF_2CHFCF_3)	HFC-236ea
HFC-236fa ($CF_3CH_2CF_3$)	HFC-236fa
HFC-245ca ($CH_2FCF_2CHF_2$)	HFC-245ca
HFC-245cb ($CF_3CF_2CH_3$)	Unspecified mix of HFCs
HFC-245ea ($CHF_2CHFCHF_2$)	Unspecified mix of HFCs
HFC-245eb ($CH_2FCHFCF_3$)	Unspecified mix of HFCs
HFC-245fa ($CHF_2CH_2CF_3$)	HFC-245fa
HFC-263fb ($CH_3CH_2CF_3$)	Unspecified mix of HFCs
HFC-272ca ($CH_3CF_2CH_3$)	Unspecified mix of HFCs
HFC-329p ($CHF_2CF_2CF_2CF_3$)	Unspecified mix of HFCs
HFC-365mfc ($CH_3CF_2CH_2CF_3$)	HFC-36mfc
HFC-1132a ($CH_2=CF_2$)	Unspecified mix of HFCs
HFC-1141 ($CH_2=CHF$)	Unspecified mix of HFCs
(Z)-HFC-1225ye ($CF_3CF=CHF(Z)$)	Unspecified mix of HFCs
(E)-HFC-1225ye ($CF_3CF=CHF(E)$)	Unspecified mix of HFCs
(Z)-HFC-1234ze ($CF_3CH=CHF(Z)$	Unspecified mix of HFCs
HFC-1234yf (($CF_3CF=CH_2$))	Unspecified mix of HFCs
(E)-HFC-1234ze (trans-$CF_3CH=CHF$)	Unspecified mix of HFCs
(Z)-HFC-1336 ($CF_3CH=CHCF_3(Z)$)	Unspecified mix of HFCs
HFC-1243zf ($CF_3CH=CH_2$)	Unspecified mix of HFCs
HFC-1345zfc ($C_2F_5CH=CH_2$)	Unspecified mix of HFCs
3,3,4,4,5,5,6,6,6- Nonafluorohex -1-ene ($C_4F_9CH=CH_2$)	Unspecified mix of HFCs
3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooct-1-ene ($C_6F_{13}CH=CH_2$)	Unspecified mix of HFCs
3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-Hep-tadecafluorodec-1-ene ($C_8F_{17}CH=CH_2$)	Unspecified mix of HFCs

PFCs	
PFC-14 (CF_4)	CF4
PFC-116 (C_2F_6)	C2F6
PFC-218 (C_3F_8)	C3F8
PFC-31-10 (C_4F_{10})	C4F10
PFC-318 (c-C_4F_8)	c-C4F8
PFC-4-1-12 (n-C_5F_{12})	C5F12
PFC-5-1-14 (n-C_6F_{14})	C6F14
Sulphuryl fluoride (SO_2F_2)	Unspecified mix of PFCs
PFC-c216 (c-C_3F_6)	c-C3F6
PFC-61-16 (n-C_7F_{16})	Unspecified mix of PFCs
PFC-71-18 (C_8F_{18})	Unspecified mix of PFCs
PFC-91-18 ($C_{10}F_{18}$)	C10F18
Perfluorobuta-1,3-diene (C_4F_6)	Unspecified mix of PFCs
Perfluorocyclopentene (c-C_5F_8)	Unspecified mix of PFCs
Perfluorodecalin (cis) (Z-$C_{10}F_{18}$)	Unspecified mix of PFCs
Perfluorodecalin (trans) (E-$C_{10}F_{18}$)	Unspecified mix of PFCs
PFC-1114 ($CF_2=CF_2$)	Unspecified mix of PFCs
PFC-1216 ($CF_3CF=CF_2$)	Unspecified mix of PFCs
Perfluorobut-1-ene ($CF_3CF_2CF=CF_2$)	Unspecified mix of PFCs
Perfluorobut-2-ene ($CF_3CF=CFCF_3$)	Unspecified mix of PFCs

SF_6

NF_3

2F1: Refrigeration and Air conditioning

2F1: Refrigeration and Air conditioning

- **Main Concepts:**

  - ***Applications or Sub-applications*** - major groupings of current and expected usage of the ODS substitutes

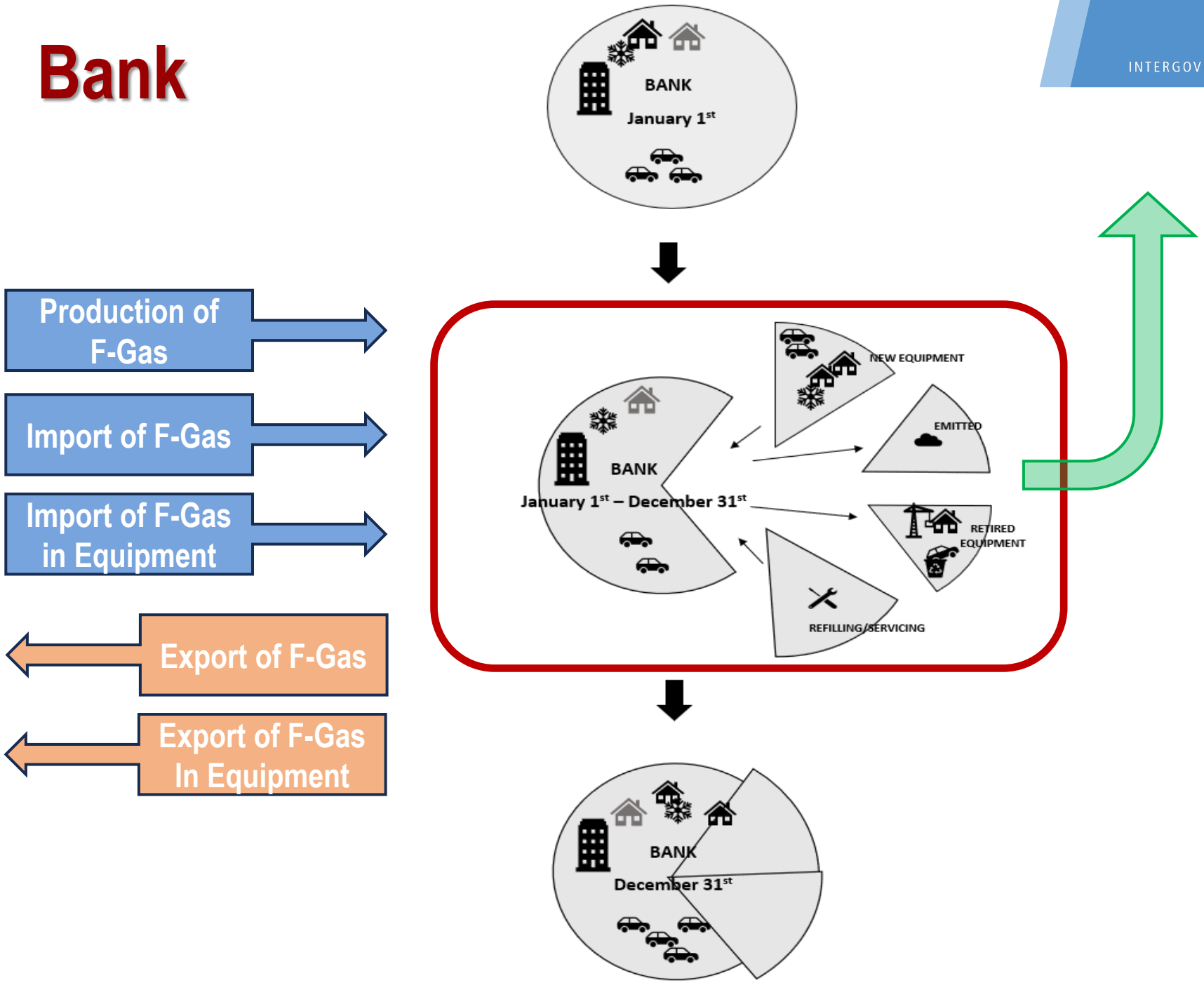
  - ***Bank:***
  - the amounts of chemical that have accumulated throughout the lifecycle, either in supply chains, products, equipment or even waste streams but which, as of the end of the most recent year, has not been emitted
  - difference between the chemical that has been consumed in an application or sub-application and that which has already been released

  - ***Tiers/Methods*:**
    - ✓*Emission Factor (a) and Mass-balance (b)*
    - ✓*Tier 1 and Tier 2*

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**	

Bank



F-gas Emissions

(amount?)

Bank = amount of F-gases contained in equipment in use.

Want to know the flow of chemicals into and out of the bank.

2F1: Tiers

- **Tier 1** *(default hybrid approach based on a historic development of the bank)*
  - **Estimates emissions at the application level** differentiating only between Stationary refrigeration and air conditioning (category 2.F.1.a) and Mobile air conditioning (category 2.F.1.b).

- **Tier 2 requires separate data for 6 sub-applications** (commercial, domestic, industrial, transport, stationary air conditioning and mobile air conditioning)
  - **Tier 2a** *(EF approach).* **Emissions = Econtainers + Echarge + Elifetime + Eend-of-life**
    - **Econtainers = RM* c/100**
    - **Echarge = M * k/100**
    - **Elifetime = B *x/100**
    - **Eend-of-life = M * p/100 * (1- n/100)**

    Emission Factors: c, k, x, p, n

  - **Tier 2b** *(mass-balance approach).*

    Emissions = Annual Sales of New Refrigerant – Total Charge of New Equipment +

    + Original Total Charge of Retiring Equipment – Amount of Intentional Destruction

    ✓ **Choice of Tier 2a or Tier 2b depends on availability of data at a national level**

2F1: Tier 1

- The Tier 1 method back-calculates the development of a bank of a refrigerant from the current reporting year to the year of its introduction.

- Enables estimation of actual emissions, even if there are no historic data available.

- Minimum data requirements /assumptions needed:

  - 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

- Defaults available for other parameters.

EQUATION 7.2B
CALCULATION OF EMISSIONS OF A CHEMICAL FROM AN APPLICATION WITH BANKS

$$\textit{Annual Emissions} = \textit{Net Consumption} \bullet \textit{Composite } EF_{FY} + \textit{Total Banked Chemical} \bullet \textit{Composite } EF_{B}$$

Tier 1 Refrigeration
Argentina - HFC-143a

HFC-143a

Current Year	2005

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

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

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

Example 1. In Country X production of specific refrigerant (HFC-143a) is 800 tonnes with additional 200 tonnes in imported equipment, making total consumption of 1 000 tonnes in 2005. *There is no data for previous years.*

To enter only:

Year of introduction of chemical - 1998
Domestic production of chemical in current year - 800
Imports of chemical in current year - 200
Exports of chemical in current year - 0
Growth rate of sales of equipment that uses the chemical – 3%

Default parameters:

Equipment lifetime – 15 years
EF from the bank – 15%
EF end-of-life destruction – 0%

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**

Tier 1 Refrigeration
Argentina - HFC-143a

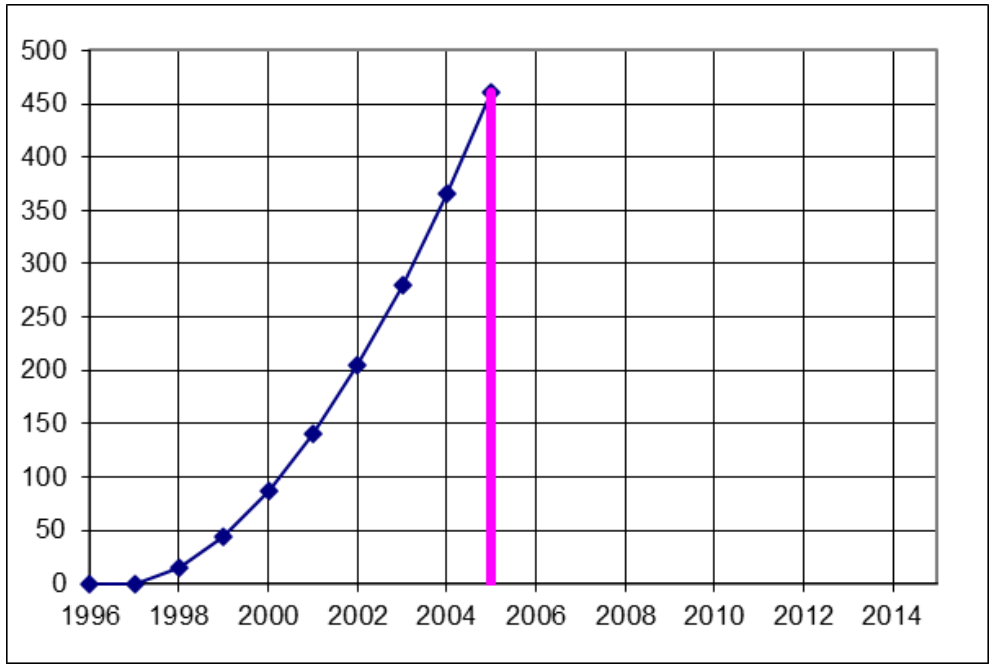
HFC-143a

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%

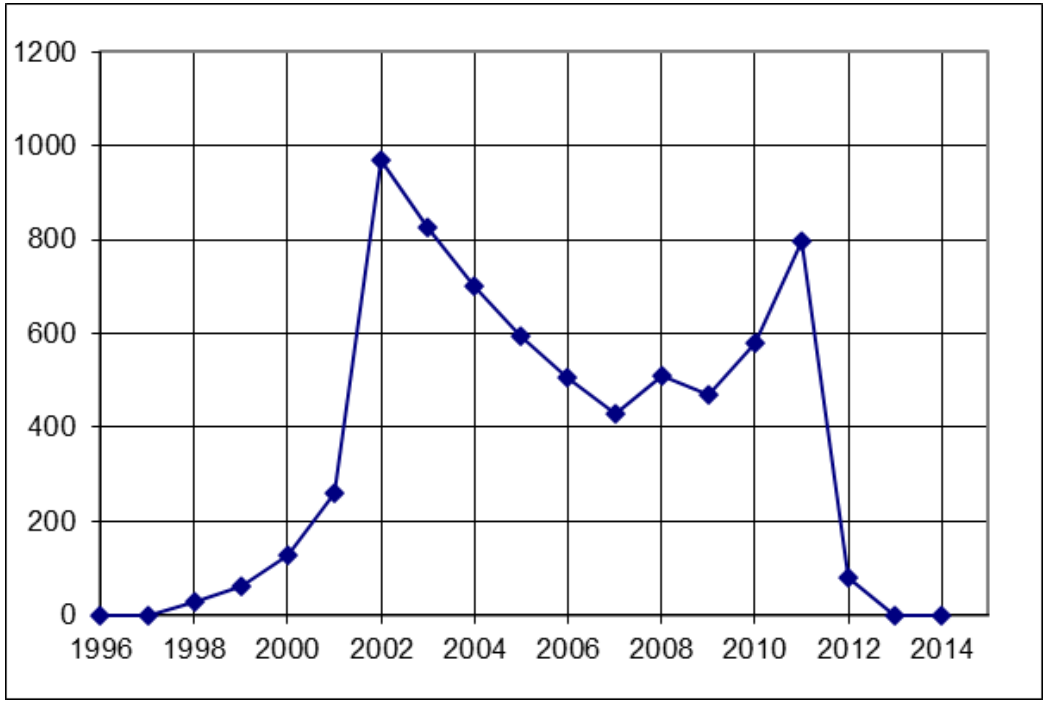
Tier 1 Defaults	
Assumed Equipment Lifetime (years)	15
Emission Factor from installed base	15%
% of HFC-143a destroyed at End-of-Life	0%



Example 1. Based on the consumption figure of 1000 tonnes, the model calculates back the development of a bank of a refrigerant from the current reporting year (2005) to the year of its introduction (1998). So, in the 2005 the bank is estimated to be 3 071 tonnes and emissions are 461 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**

Example 2. Country X imported the refrigerant HFC-134a in years 1998-2002 only. There is no production, export and import after 2002 *(the import data for 1998-2002 presented in the table below).*



Based on the import data and default factors from Example 1 *(except lifetime is 10 years),* **it can be estimated that emissions still will take place till 2012 taking into account development of the bank and emissions from retired equipment.**

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Production																		
Agent in Exports																		
Agent in Imports		200	250	500	1000	5000												
Total New Agent in Domestic Equipment		200	250	500	1000	5000												
Agent in Retired Equipment												170	213	425	784	81		
Destruction of agent in retired equipment												0	0	0	0	0		
Release of agent from retired equipment												170	213	425	784	81		
Bank		200	420	857	1728	6469	5499	4674	3973	3377	2870	2270	1717	1034	95	0	0	0
Emission		30	63	129	259	970	825	701	596	507	431	510	470	580	799	81	0	0

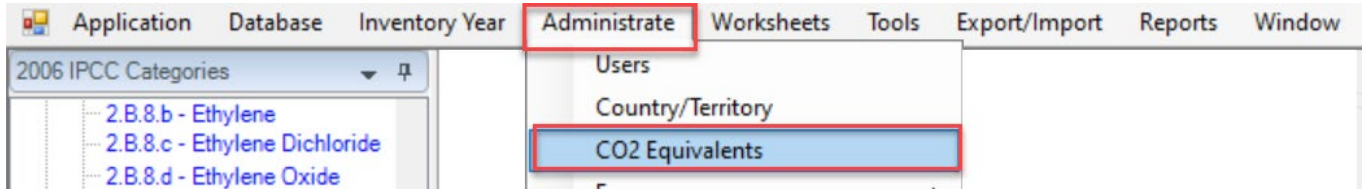
✓ *Now let's see how it is realized in the Software*

Step 1: Customize GWP values (AR5)

Step 2: Customize F-gases in F-gas Manager

GWP / CO_2 Equivalents

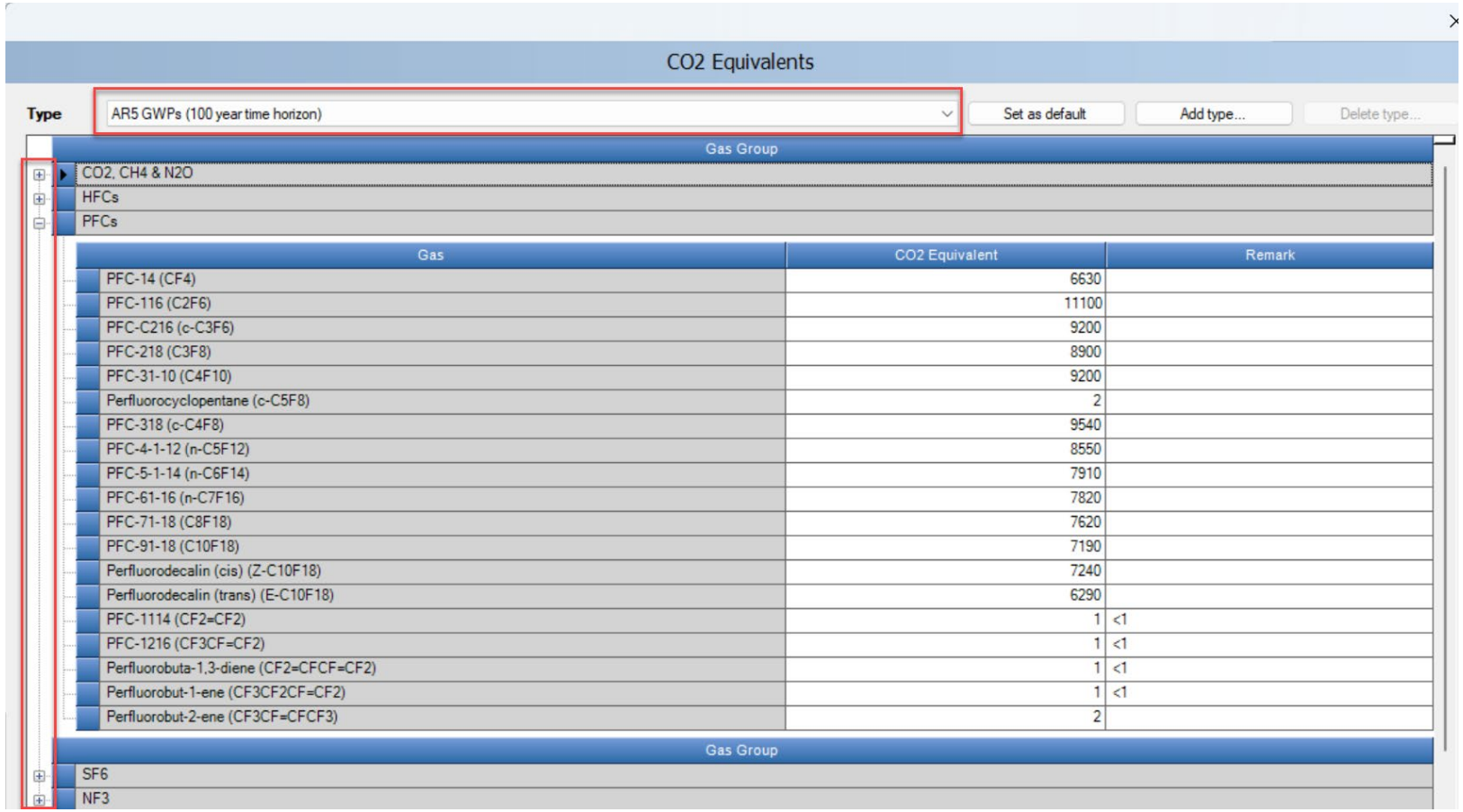
- User may view list of F-gases and CO_2 equivalents used in the Software.



- Confirm if Software shows CO_2 equivalents as in AR5. Go to **Administrate** tab

(AR5 GWPs are set by default in latest versions of Software, unless changed by user).

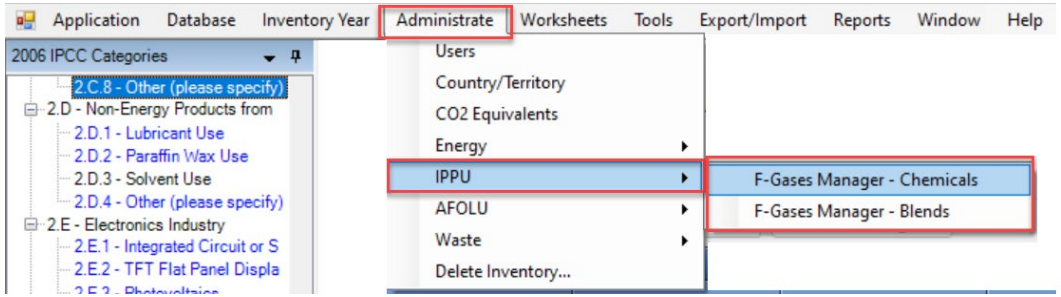
- F-gases and blends may be added, if needed, through the F-gases Manager.



F-gases Manager

- **Purpose of F-gases Manager:**
  - Identify all F-gases consumed (including imported) and/or produced/emitted in the country.
  - Customize *Software* so limited to F-gases relevant for the user.
  - Designate specific gas/category confidential, if applicable, for UNFCCC reporting.
  - Ultimately to minimize double counting.

- **F-gases Manager to be set up for individual F-gas species and blends**



Two elements of the Manager:
- Chemicals
- Blends

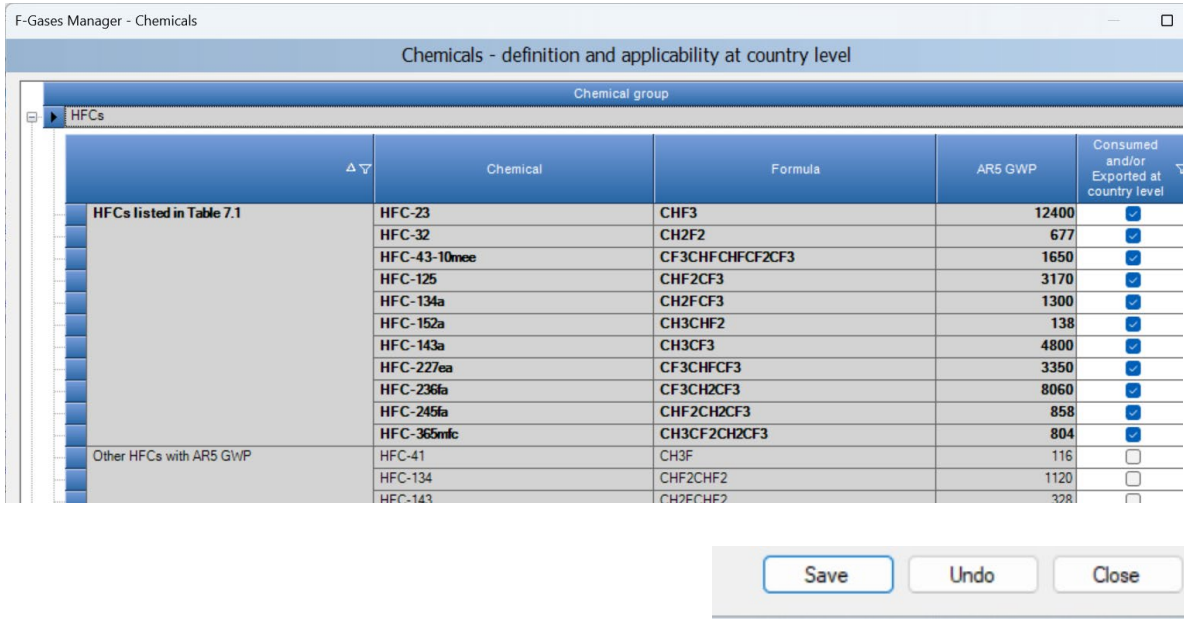
- **2-step process**
  - List F-gases /blends relevant at country level – done through main **Administrate** tab, then
  - Identify those relevant for individual IPCC category – done at **worksheet** level.

F-gases Manager – Country level

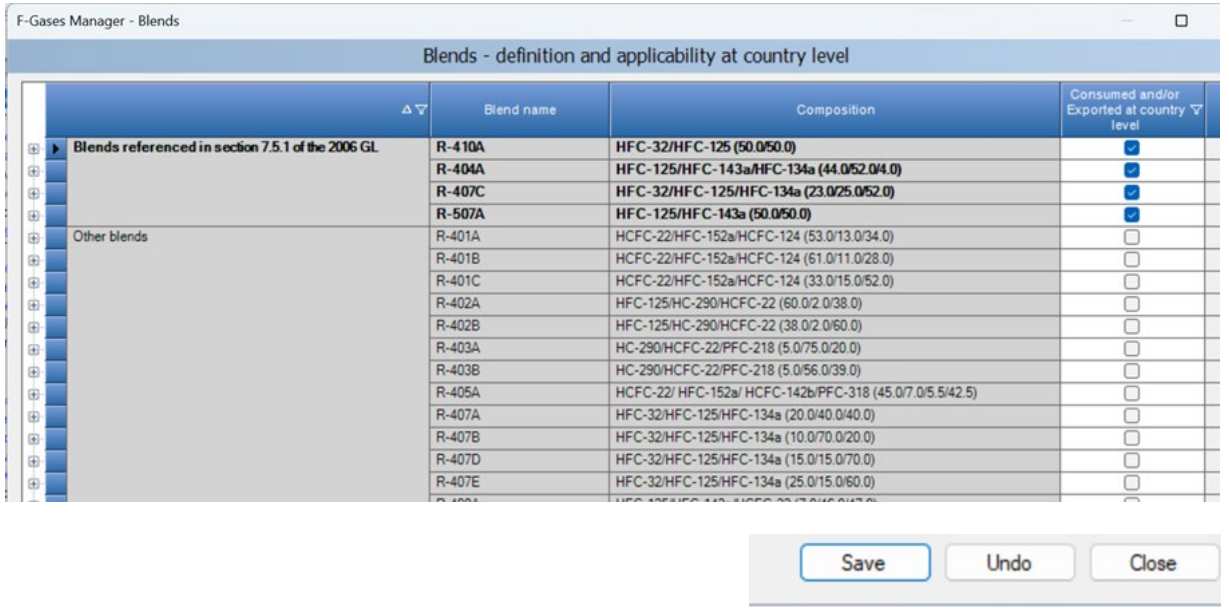
1. **Check/uncheck boxes for F-gases:**
   - ✓ Produced
   - ✓ Imported
   - ✓ Exported
   - ✓ Emitted as Fugitive

2. **Check/uncheck boxes for Blends:**
   Preferable to do inventory calculations based on individual F-gas species and not blends. The Software can accommodate blends, but user should ensure there is no double counting with F-gas species.

Chemicals



Blends



F-gases Manager – Country level

1. User may add country-specific F-gases and Blends using row with [+]
2. For Blends, information on the composition must also be added

Chemicals

Chemicals - definition and applicability at country level

Chemical group	Chemical	Formula	AR5 GWP	Consumed and/or Exported at country level
HFCs				
PFCs				
PFCs listed in Table 7.1	**PFC-14**	**CF4**	**6630**	☑
	PFC-116	**C2F6**	**11100**	☑
	PFC-218	**C3F8**	**8900**	☑
	PFC-31-10	**C4F10**	**9200**	☑
	PFC-5-1-14	**n-C6F14**	**7910**	☑
Other PFCs with AR5 GWP	PFC-C216	c-C3F6	9200	☐
	Perfluorocyclopentane	c-C5F8	2	☐
	PFC-318	c-C4F8	9540	☐
	PFC-4-1-12	n-C5F12	8550	☐
	PFC-61-16	n-C7F16	7820	☐
	PFC-71-18	C8F18	7620	☐
	PFC-91-18	C10F18	7190	☐
	Perfluorodecalin (cis)	Z-C10F18	7240	☐
	Perfluorodecalin (trans)	E-C10F18	6290	☐
	PFC-1114	CF2=CF2	1	☐
	PFC-1216	CF3CF=CF2	1	☐
	Perfluorobuta-1,3-diene	CF2=CFCF=CF2	1	☐
	Perfluorobut-1-ene	CF3CF2CF=CF2	1	☐
	Perfluorobut-2-ene	CF3CF=CFCF3	2	☐
User-defined PFCs	INSERT country specific name	INSERT country specific formula	200	☑

Blends

F-Gases Manager - Blends

Blends - definition and applicability at country level

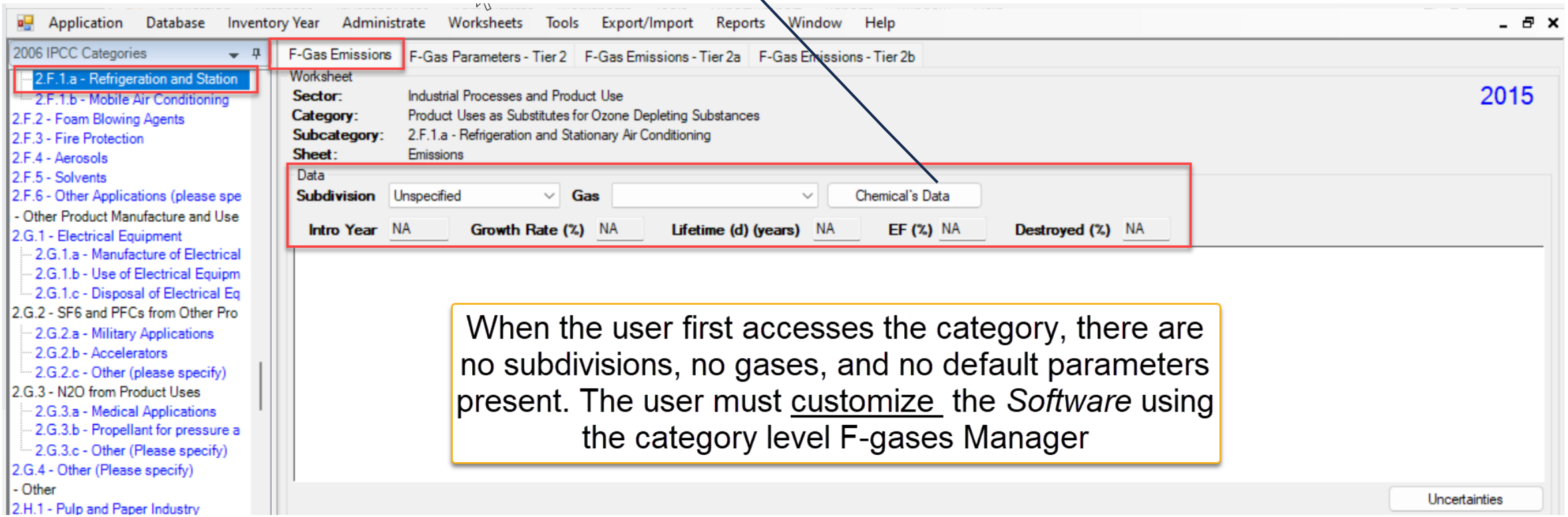
Blend name	Composition	Consumed and/or Exported at country level
R-412A	HCFC-22/PFC-218/HCFC-142b (70.0/5.0/25.0)	☐
R-413A	PFC-218/HFC-134a/HC-600a (9.0/88.0/3.0)	☐
R-515A	HCFC-22/HFC-152a (82.0/18.0)	☐
R-515B	HCFC-22/HFC-152a (25.0/75.0)	☐
R-416A	HFC-134a/HCFC-124/HC-600 (59.0/39.5/1.5)	☐
R-417A	HFC-125/HFC-134a/HC-600 (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-503	HFC-23/CFC-13 (40.1/59.9)	☑
R-504	HFC-32/CFC-115 (48.2/51.8)	☐
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)	☐
XYZ	INSERT composition	☑

Constituent	AR5 GWP	Composition (%)
HFC-23	12400	25
HFC-125	3170	25

Step 3: Enter AD for Tier 1

2F1: Tier 1

For Tier 1, access to the category-level F-gases Manager through Chemicals' Data tab

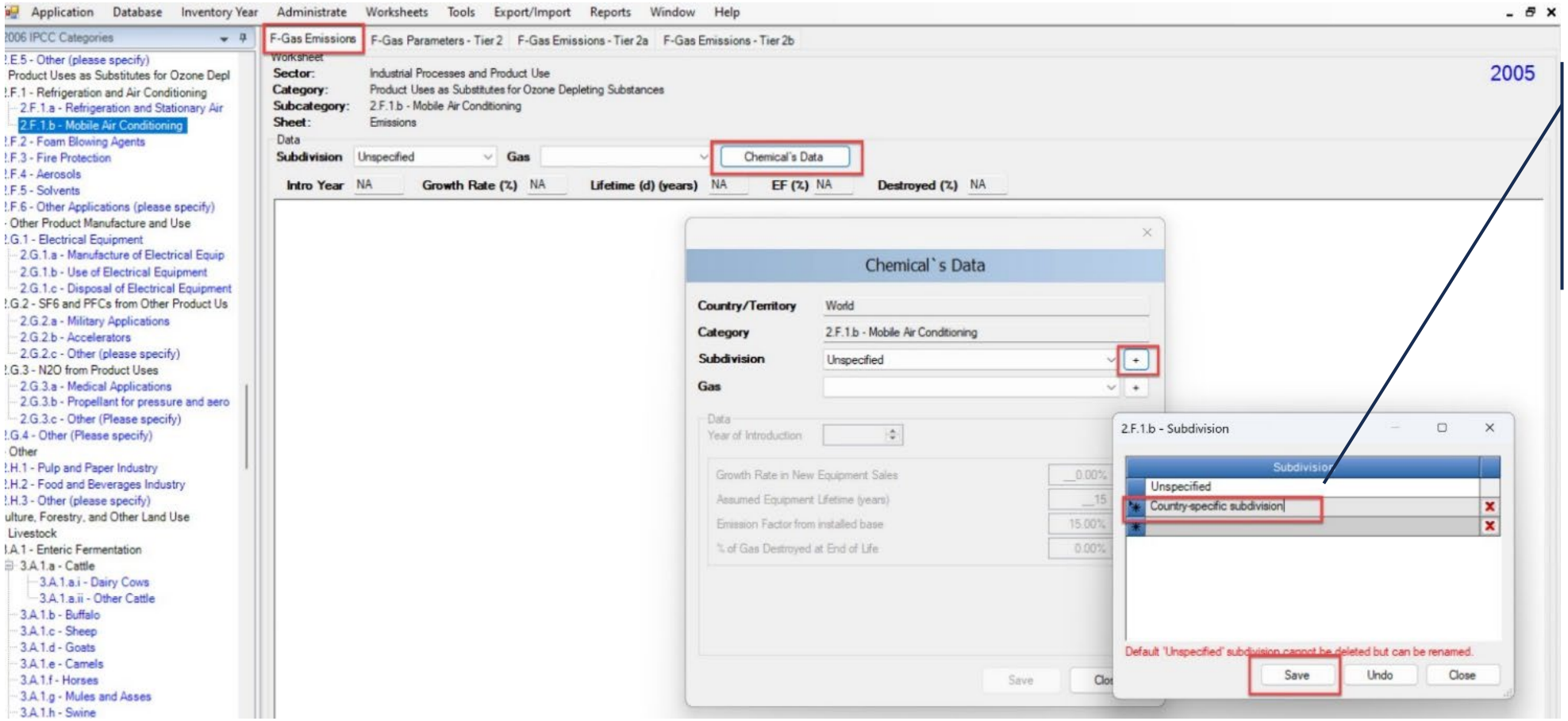


When the user first accesses the category, there are no subdivisions, no gases, and no default parameters present. The user must customize the *Software* using the category level F-gases Manager

Chemical's Data tab:

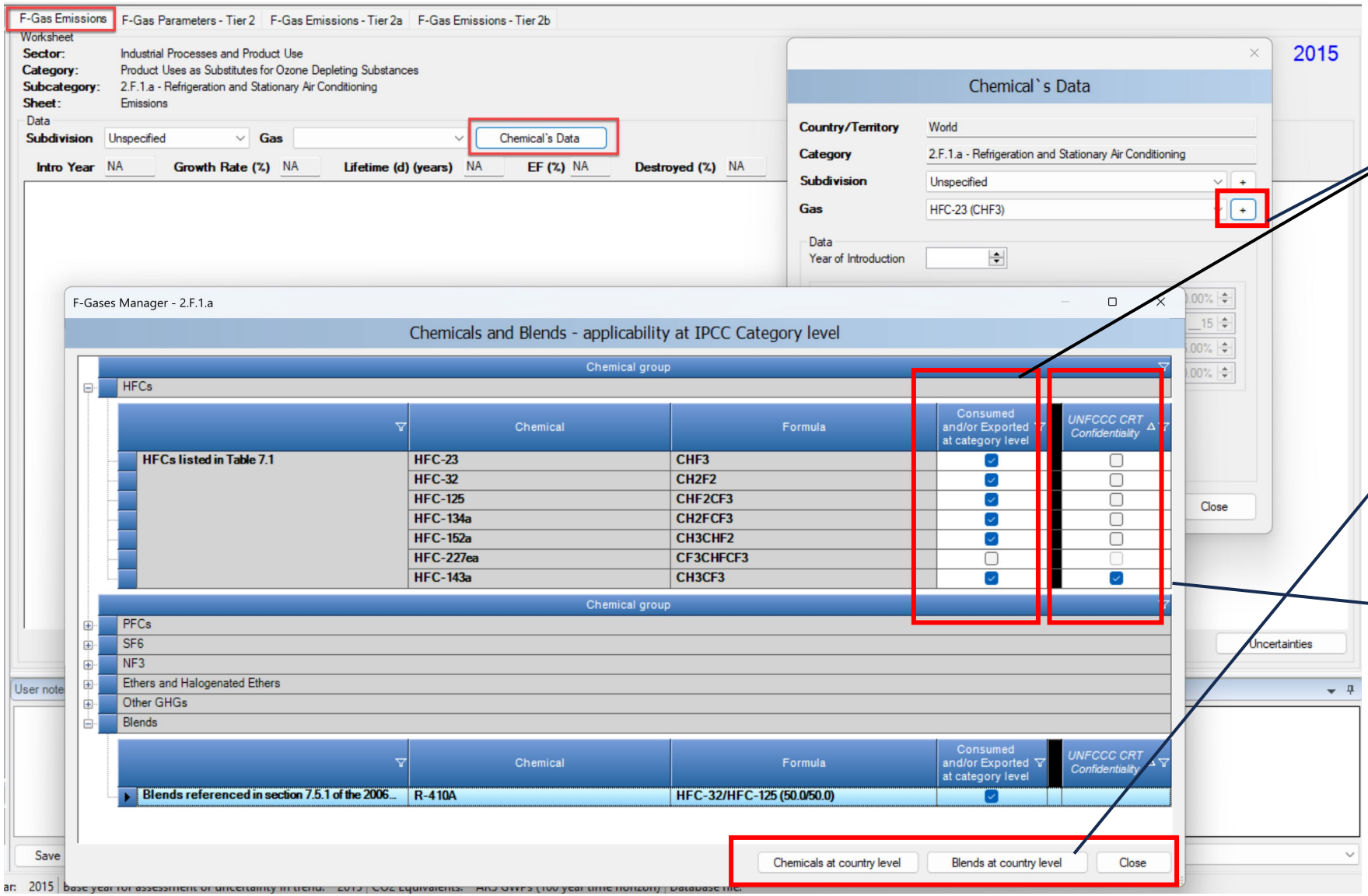
- ✓ Add relevant F-gases for IPCC category
- ✓ Add subdivisions, if applicable
- ✓ Add parameters

2F1: Tier 1



1. Enter subdivision(s) for country – may be single national or multiple.

2F1: Tier 1



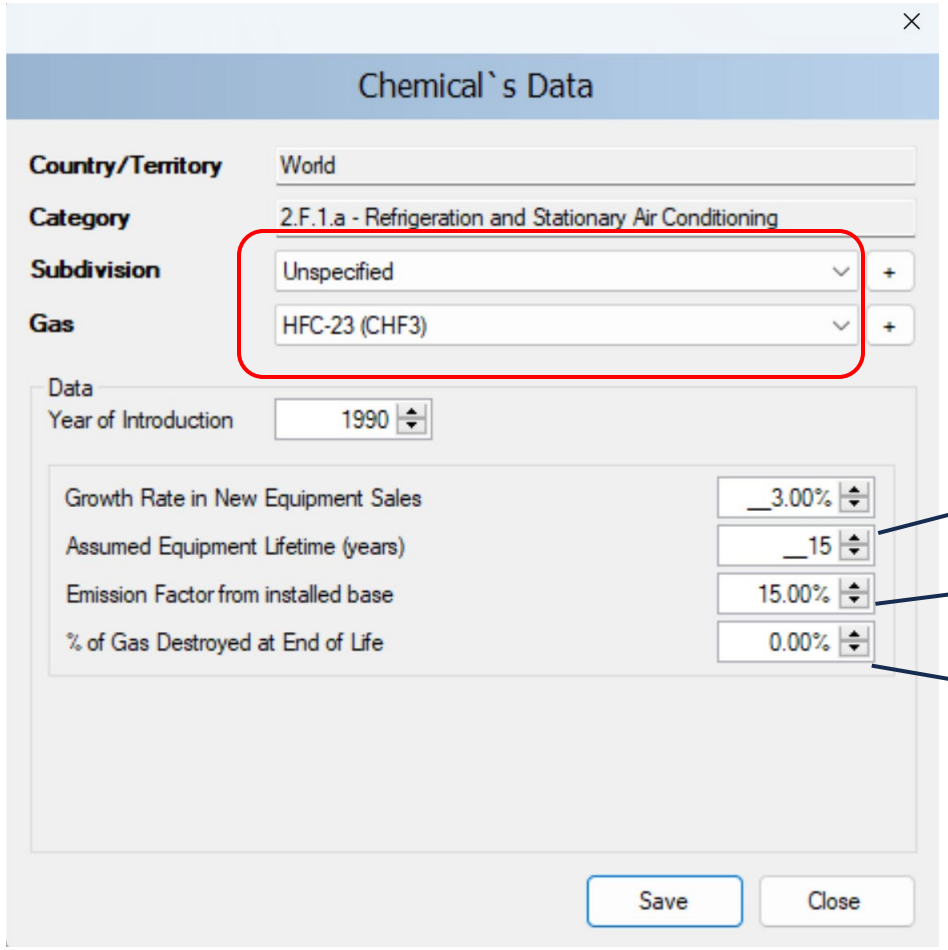
2. Select gases consumed (including imported) and/or exported in the IPCC category level F-gases Manager.

3. If gas not available for selection, must first be selected in national level F-gases Manager.

4. **For interoperability:** user may indicate if the gas in this category is confidential- all confidential emissions will be reported, in tCO_2 eq in 2.H.3 as unspecified mix of HFCs and PFCs.

2F1: Tier 1

Then, for each combination of subdivision and gas/blend, enter parameters:



Default is 15 years

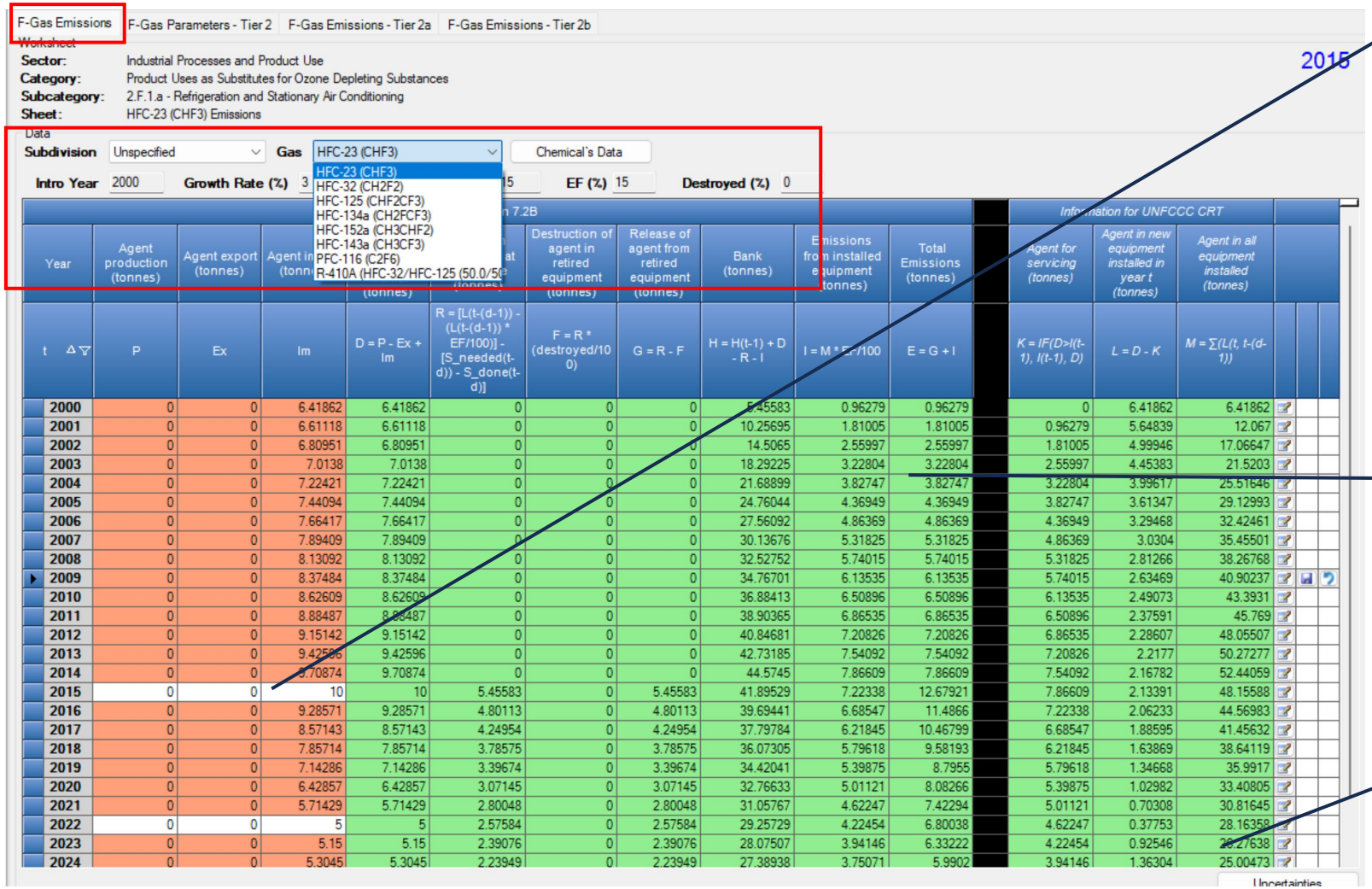
Default is 15%

Generally, where information is not available for a GHG Inventory, destruction is assumed to be 0

Source: Figure 7.7 of Volume 3 Chapter 7 of the 2006 IPCC Guidelines

2F1: Example for Tier 1

Then, the user enters consumption data for each gas/blend



Consumption data entered for each gas, must know at least current year (but should add all known years). Consumption for unknown years extrapolated back based on equipment growth rate.

Green cells automatically calculated based on parameters entered.

Column E = Total Emissions
Columns K, L, M calculated AD for interoperability.

2F1: Example for Tier 1

F-Gas Emissions | F-Gas Parameters - Tier 2 | F-Gas Emissions - Tier 2a | F-Gas Emissions - Tier 2b

Worksheet

Sector: Industrial Processes and Product Use
Category: Product Uses as Substitutes for Ozone Depleting Substances
Subcategory: 2.F.1.a - Refrigeration and Stationary Air Conditioning
Sheet: HFC-23 (CHF3) Emissions

Data

Subdivision Unspecified **Gas** HFC-23 (CHF3) Chemical's Data

Intro Year 2000 **Growth Rate (%)** 3 **Lifetime (d) (years)** 15 **EF (%)** 15 **Destroyed (%)** 0

2015

	Equation 7.2B										Information for UNFCCC CRT		
Year	Agent production (tonnes)	Agent export (tonnes)	Agent import (tonnes)	Total new agent to domestic market (tonnes)	Retired in equipment at end-of-life (tonnes)	Destruction of agent in retired equipment (tonnes)	Release of agent from retired equipment (tonnes)	Bank (tonnes)	Emissions from installed equipment (tonnes)	Total Emissions (tonnes)	*Agent for servicing (tonnes)*	*Agent in new equipment installed in year t (tonnes)*	*Agent in all equipment installed (tonnes)*
t	P	Ex	Im	D = P - Ex + Im	R = [L(t-(d-1)) - (L(t-(d-1)) * EF/100)] - [S_needed(t-d)) - S_done(t-d)]	F = R * (destroyed/100)	G = R - F	H = H(t-1) + D - R - I	I = M * EF/100	E = G + I	*K = IF(D>I(t-1), I(t-1), D)*	*L = D - K*	*M = Σ(L(t, t-(d-1))*
2000	0	0	6.41862	6.41862	0	0	0	5.45583	0.96279	0.96279	0	6.41862	6.41862
2001	0	0	6.61118	6.61118	0	0	0	10.25695	1.81005	1.81005	0.96279	5.64839	12.067
2002	0	0	6.80951	6.80951	0	0	0	14.5065	2.55997	2.55997	1.81005	4.99846	17.06647
2003	0	0	7.0138	7.0138	0	0	0	18.29225	3.22804	3.22804	2.55997	4.45383	21.5203
2004	0	0	7.22421	7.22421	0	0	0	21.68899	3.82747	3.82747	3.22804	3.99617	25.51646
2005	0	0	7.44094	7.44094	0	0	0	24.76044	4.36949	4.36949	3.82747	3.61347	29.12993
2006	0	0	7.66417	7.66417	0	0	0	27.56092	4.86369	4.86369	4.36949	3.29468	32.42461
2007	0	0	7.89409	7.89409	0	0	0	30.13676	5.31825	5.31825	4.86369	3.0304	35.45501
2008	0	0	8.13092	8.13092	0	0	0	32.52752	5.74015	5.74015	5.31825	2.81266	38.26768
2009	0	0	8.37484	8.37484	0	0	0	34.76701	6.13535	6.13535	5.74015	2.63469	40.90237
2010	0	0	8.62609	8.62609	0	0	0	36.88413	6.50896	6.50896	6.13535	2.49073	43.3931
2011	0	0	8.88487	8.88487	0	0	0	38.90365	6.86535	6.86535	6.50896	2.37591	45.769
2012	0	0	9.15142	9.15142	0	0	0	40.84681	7.20826	7.20826	6.86535	2.28607	48.05507
2013	0	0	9.42596	9.42596	0	0	0	42.73185	7.54092	7.54092	7.20826	2.2177	50.27277
2014	0	0	9.70874	9.70874	0	0	0	44.5745	7.86609	7.86609	7.54092	2.16782	52.44059
2015	0	0	10	10	5.45583	0	5.45583	41.89529	7.22338	12.67921	7.86609	2.13391	48.15588
2016	0	0	9.28571	9.28571	4.80113	0	4.80113	39.69441	6.68547	11.4866	7.22338	2.06233	44.56983
2017	0	0	8.57143	8.57143	4.24954	0	4.24954	37.79784	6.21845	10.46799	6.68547	1.88595	41.45632
2018	0	0	7.85714	7.85714	3.78575	0	3.78575	36.07305	5.79618	9.58193	6.21845	1.63869	38.64119
2019	0	0	7.14286	7.14286	3.39674	0	3.39674	34.42041	5.39875	8.7955	5.79618	1.34668	35.9917
2020	0	0	6.42857	6.42857	3.07145	0	3.07145	32.76633	5.01121	8.08266	5.39875	1.02982	33.40805
2021	0	0	5.71429	5.71429	2.80048	0	2.80048	31.05767	4.62247	7.42294	5.01121	0.70308	30.81645
2022	0	0	5	5	2.57584	0	2.57584	29.25729	4.22454	6.80038	4.62247	0.37753	28.16358

1. Note that after the EFs/ parameters for a gas are entered in "Chemical's Data" the parameters appear here, and a worksheet for data entry appears.

2. AD are entered in orange cells. Where country-specific data are entered (e.g. 2015, 2022), cells become white. Remaining orange cells are calculated/ interpolated based on the growth rate.
Note: Do NOT add zeros for years data are not known, the system will interpolate from a "0"

3. Green cells are calculated.

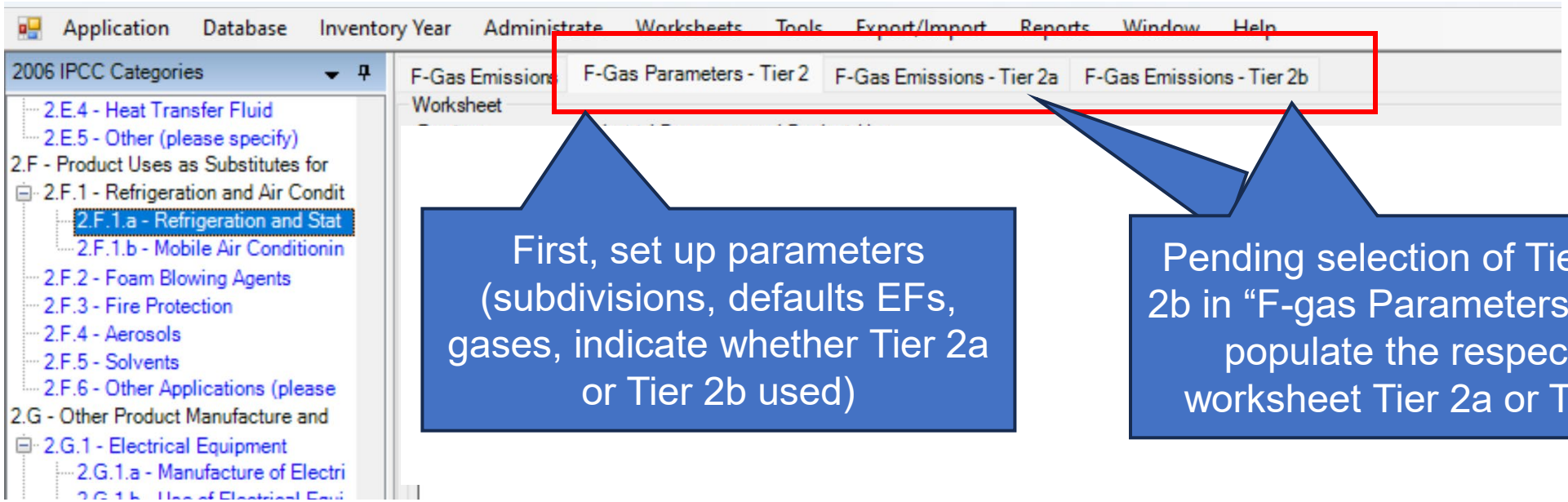
4. Note that although the user is in the 2015 inventory year, F-gases are calculated for entire time series.

2F1 Refrigeration and Air Conditioning

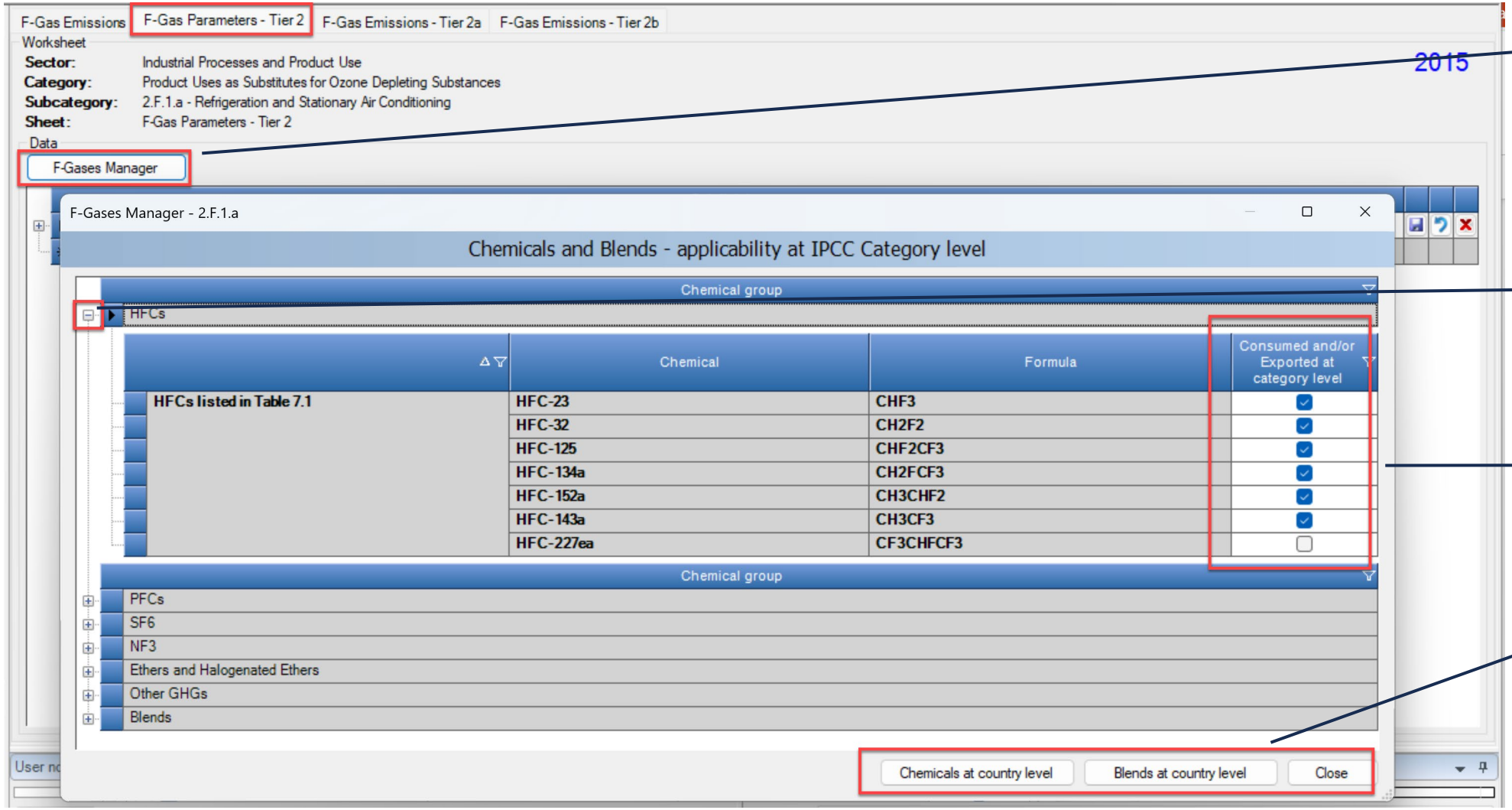
Tier 2

(if 2F1 is a key category)

2F1: Steps for Tier 2



2F1: F-Gas Parameters – Tier 2



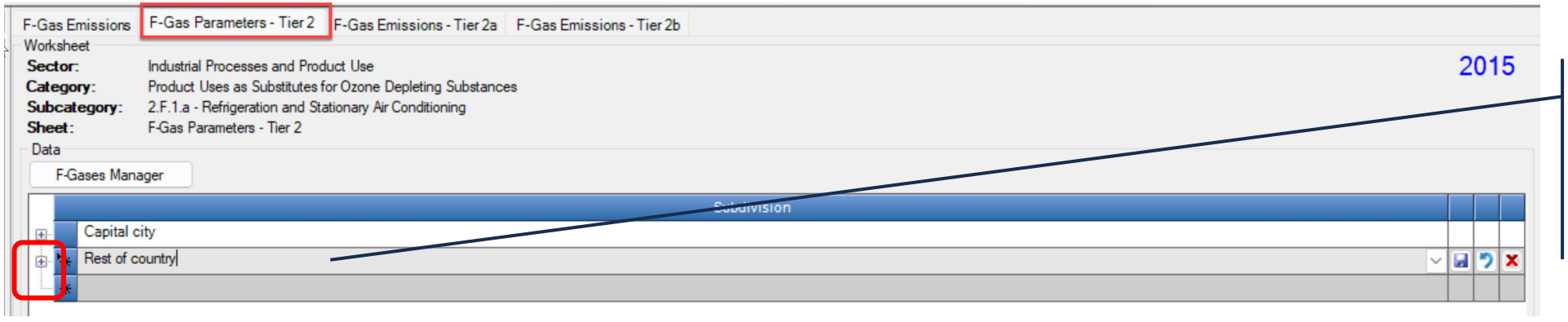
1. Select **F-Gases Manager** to set up category level F-gases Manager.

2. In pop-up box, select [+] to open drop-downs for gas/blend.

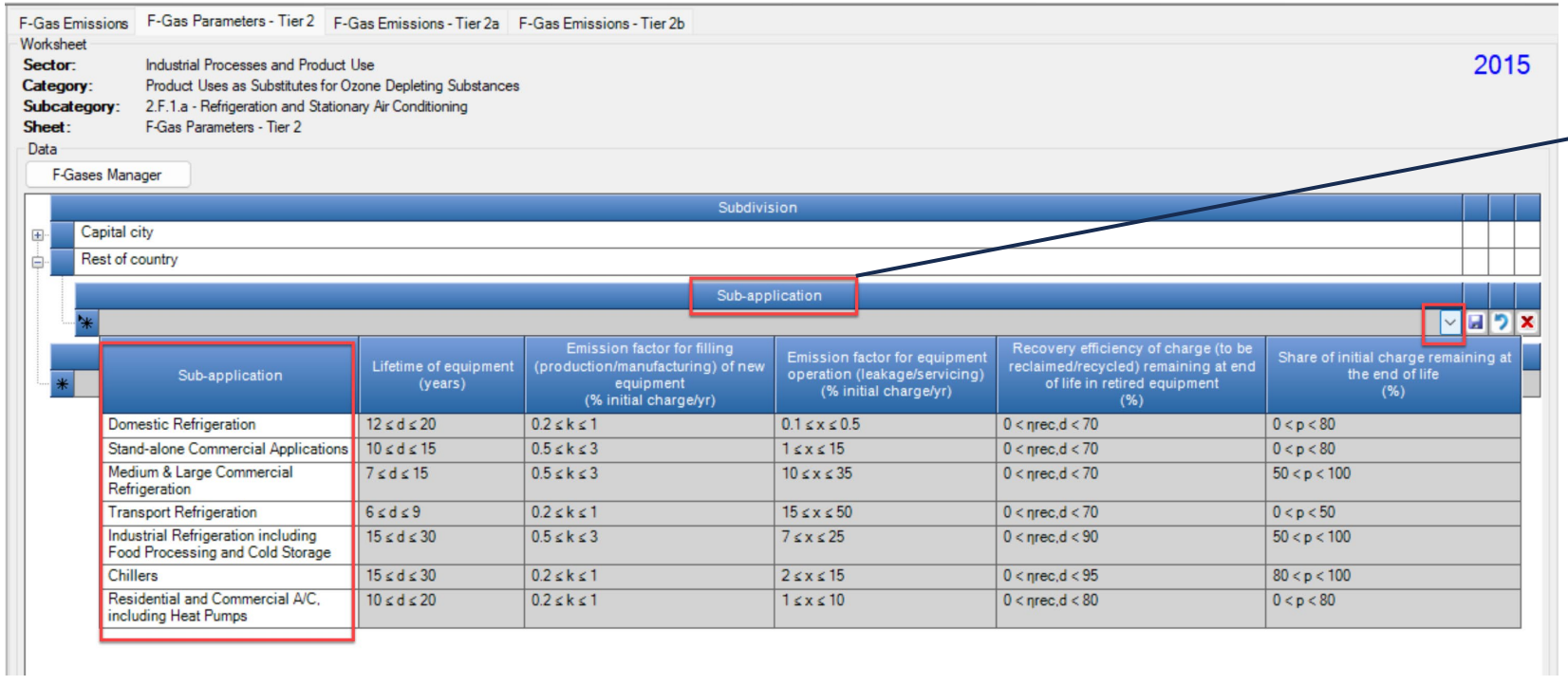
3. Select species/blends relevant for 2.F.1.

4. If gas not available for selection, must first be selected in national level F-gases Manager.

2F1: Subdivisions and Sub-applications



5. Enter subdivision(s) for country – may be single national or multiple. Add subdivisions by directly typing in row.

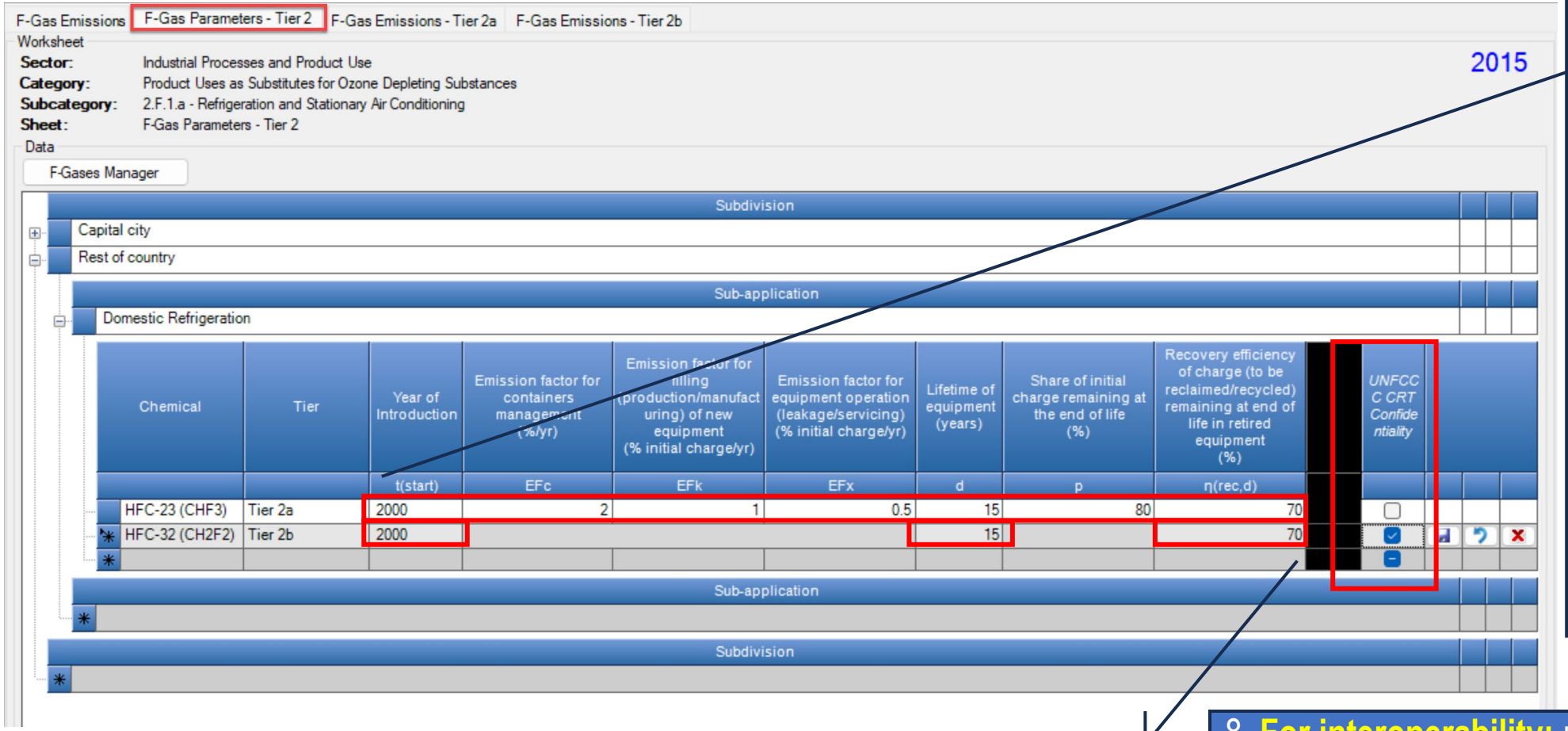


Sub-application	Lifetime of equipment (years)	Emission factor for filling (production/manufacturing) of new equipment (% initial charge/yr)	Emission factor for equipment operation (leakage/servicing) (% initial charge/yr)	Recovery efficiency of charge (to be reclaimed/recycled) remaining at end of life in retired equipment (%)	Share of initial charge remaining at the end of life (%)
Domestic Refrigeration	$12 \le d \le 20$	$0.2 \le k \le 1$	$0.1 \le x \le 0.5$	$0 < \eta rec,d < 70$	$0 < p < 80$
Stand-alone Commercial Applications	$10 \le d \le 15$	$0.5 \le k \le 3$	$1 \le x \le 15$	$0 < \eta rec,d < 70$	$0 < p < 80$
Medium & Large Commercial Refrigeration	$7 \le d \le 15$	$0.5 \le k \le 3$	$10 \le x \le 35$	$0 < \eta rec,d < 70$	$50 < p < 100$
Transport Refrigeration	$6 \le d \le 9$	$0.2 \le k \le 1$	$15 \le x \le 50$	$0 < \eta rec,d < 70$	$0 < p < 50$
Industrial Refrigeration including Food Processing and Cold Storage	$15 \le d \le 30$	$0.5 \le k \le 3$	$7 \le x \le 25$	$0 < \eta rec,d < 90$	$50 < p < 100$
Chillers	$15 \le d \le 30$	$0.2 \le k \le 1$	$2 \le x \le 15$	$0 < \eta rec,d < 95$	$80 < p < 100$
Residential and Commercial A/C, including Heat Pumps	$10 \le d \le 20$	$0.2 \le k \le 1$	$1 \le x \le 10$	$0 < \eta rec,d < 80$	$0 < p < 80$

6. Select sub-applications.

Note for interoperability:
It is best to select from pre-defined list and not alter. Any user-specific sub-applications will be reported together under Stationary Air Conditioning in CRT

2F1: Parameters



7. For each sub-application, select Tier used.

Default parameters / EFs here must be filled before estimating emissions.

Each Tier has different data requirements.

8. **For interoperability:** user may indicate if the gas in this category is confidential- all confidential emissions will be reported, in tCO_2 eq in 2.H.3 as unspecified mix of HFCs and PFCs.

2F1 Refrigeration and Air Conditioning

Tier 2a

2F1: Tier 2a

- **Tier 2a** *(Emission Factor Approach):*

EQUATION 7.10
SUMMARY OF SOURCES OF EMISSIONS

$$E_{total,t} = E_{containers,t} + E_{Charge,t} + E_{lifetime,t} + E_{end-of-life,t}$$

$E_{containers,t}$	$E_{Charge,t}$	$E_{lifetime,t}$	$E_{end-of-life,t}$
HFC market for new equipment and servicing * EF for container management	HFC charged into new equipment * EF for losses during charging	HFC banked in existing systems * EF from annual leakage during use/servicing	Initial HFC charged in new equipment * residual charge (% of initial at end of life) * (1 – recovery efficiency at disposal)

2F1: Tier 2a

The Tier 2a worksheet will be blank until all EFs and Parameters are added in worksheet <F-gas Parameters – Tier 2>

F-Gas Emissions | F-Gas Parameters - Tier 2 | **F-Gas Emissions - Tier 2a** | F-Gas Emissions - Tier 2b

Worksheet

Sector: Industrial Processes and Product Use
Category: Product Uses as Substitutes for Ozone Depleting Substances
Subcategory: 2.F.1.a - Refrigeration and Stationary Air Conditioning
Sheet: F-Gas Emissions - Emission Factor Approach - Tier 2a

2015

Data

Subdivision | **Sub-application** | **Gas**

Intro Year | **EFc [%]** | **EFk [%]** | **EFx [%]** | **Lifetime (d) [yr]** | **p [%]** | **η(rec,d) [%]**

Equation 7.10 - 7.14

Year	Amount in the bank on January 1st of year t (kg)	Domestically Manufactured HFC in year t (kg)	Imported in bulk in year t (kg)	Exported in bulk in year t (kg)	Contained in factory-charged Imported equipment in year t	Contained in factory-charged Exported new -equipment in year t	Domestic Sales of chemical (in bulk) in year t (kg)	Emitted by containers management (during transfer from bulk to small,	Used to fill domestically manufactured new equipment in year t	Emitted during filling of new equipment in year t (kg)	Contained in new equipment filled in country in year t	Contained in equipment going to the bank in year t (kg)	Emitted from equipment in use in year t, including servicing (kg)
t Δ	B = U(t-1)	C	D	E	F	G	H = C + D - E + Q(t-1)	I = H * (EFc / 100)	J = H - I - O	K = J * (EFk / 100)	L = J - K	M = L + F - G	N = ∑(M(t-d+1,t)) * (EFx / 100)

F-Gas Emissions | **F-Gas Parameters - Tier 2** | F-Gas Emissions - Tier 2a | F-Gas Emissions - Tier 2b

Worksheet

Sector: Industrial Processes and Product Use
Category: Product Uses as Substitutes for Ozone Depleting Substances
Subcategory: 2.F.1.a - Refrigeration and Stationary Air Conditioning
Sheet: F-Gas Parameters - Tier 2

2015

Data

F-Gases Manager

Subdivision

- Capital city
- Rest of country

Sub-application

- Domestic Refrigeration

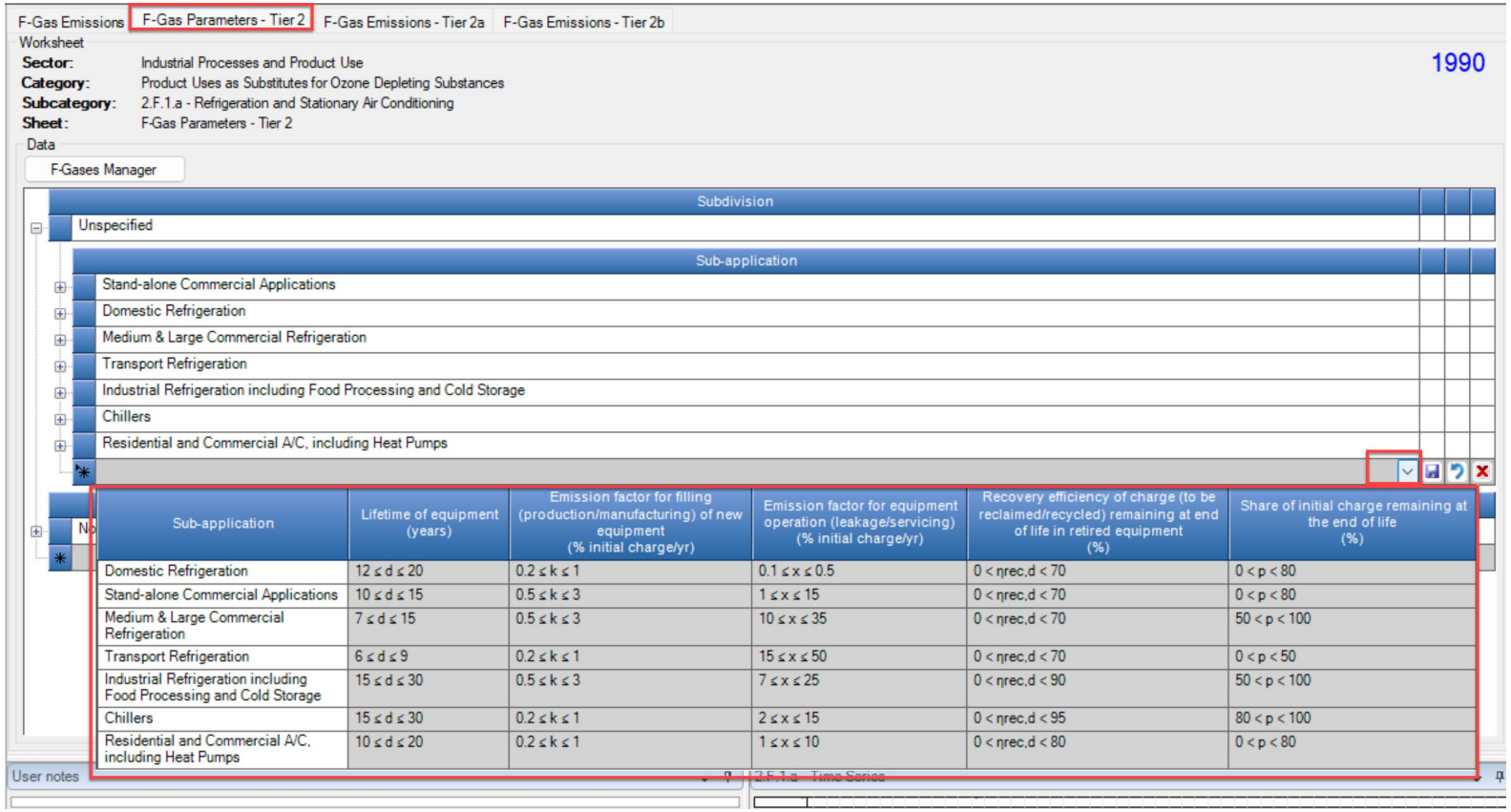
Chemical	Tier	Year of Introduction	Emission factor for containers management (%/yr)	Emission factor for filling (production/manufacturing) of new equipment (% initial charge/yr)	Emission factor for equipment operation (leakage/servicing) (% initial charge/yr)	Lifetime of equipment (years)	Share of initial charge remaining at the end of life (%)	Recovery efficiency of charge (to be reclaimed/recycled) remaining at end of life in retired equipment (%)		UNFCCC CRT Confidentiality
		t(start)	EFc	EFk	EFx	d	p	η(rec,d)		
HFC-23 (CHF3)	Tier 2a	2000	2	1	0.5	12	80	35		☐

Sub-application

Subdivision

2F1: Tier 2a – EFs

Default parameters and EFs can be found in the drop-down table in the worksheet <F-Gas Parameters-Tier 2> which is copied from Table 7.9 of the 2006 IPCC Guidelines (EF for container management between 2-10% as per equation 7.11)



Sub-application	Lifetime of equipment (years)	Emission factor for filling (production/manufacturing) of new equipment (% initial charge/yr)	Emission factor for equipment operation (leakage/servicing) (% initial charge/yr)	Recovery efficiency of charge (to be reclaimed/recycled) remaining at end of life in retired equipment (%)	Share of initial charge remaining at the end of life (%)
Domestic Refrigeration	12 ≤ d ≤ 20	0.2 ≤ k ≤ 1	0.1 ≤ x ≤ 0.5	0 < ηrec,d < 70	0 < p < 80
Stand-alone Commercial Applications	10 ≤ d ≤ 15	0.5 ≤ k ≤ 3	1 ≤ x ≤ 15	0 < ηrec,d < 70	0 < p < 80
Medium & Large Commercial Refrigeration	7 ≤ d ≤ 15	0.5 ≤ k ≤ 3	10 ≤ x ≤ 35	0 < ηrec,d < 70	50 < p < 100
Transport Refrigeration	6 ≤ d ≤ 9	0.2 ≤ k ≤ 1	15 ≤ x ≤ 50	0 < ηrec,d < 70	0 < p < 50
Industrial Refrigeration including Food Processing and Cold Storage	15 ≤ d ≤ 30	0.5 ≤ k ≤ 3	7 ≤ x ≤ 25	0 < ηrec,d < 90	50 < p < 100
Chillers	15 ≤ d ≤ 30	0.2 ≤ k ≤ 1	2 ≤ x ≤ 15	0 < ηrec,d < 95	80 < p < 100
Residential and Commercial A/C, including Heat Pumps	10 ≤ d ≤ 20	0.2 ≤ k ≤ 1	1 ≤ x ≤ 10	0 < ηrec,d < 80	0 < p < 80

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 ≤ M ≤ 0.5	12 ≤ d ≤ 20	0.2 ≤ k ≤ 1	0.1 ≤ x ≤ 0.5	0 < $\eta_{rec,d}$ < 70	0 < p < 80
Stand-alone Commercial Applications	0.2 ≤ M≤ 6	10 ≤ d ≤ 15	0.5 ≤ k ≤ 3	1 ≤ x ≤ 15	0 < $\eta_{rec,d}$ < 70	0 < p < 80
Medium & Large Commercial Refrigeration	50 ≤ M ≤ 2000	7 ≤ d ≤ 15	0.5 ≤ k ≤ 3	10 ≤ x ≤ 35	0 < $\eta_{rec,d}$ < 70	50 < p < 100
Transport Refrigeration	3 ≤ M ≤ 8	6 ≤ d ≤ 9	0.2 ≤ k ≤ 1	15 ≤ x ≤ 50	0 < $\eta_{rec,d}$ < 70	0 < p < 50
Industrial Refrigeration including Food Processing and Cold Storage	10 ≤ M ≤ 10,000	15 ≤ d ≤ 30	0.5 ≤ k ≤ 3	7 ≤ x ≤ 25	0 < $\eta_{rec,d}$ < 90	50 < p < 100
Chillers	10 ≤ M≤ 2000	15 ≤ d ≤ 30	0.2 ≤ k ≤ 1	2 ≤ x ≤ 15	0 < $\eta_{rec,d}$ < 95	80 < p < 100
Residential and Commercial A/C, including Heat Pumps	0.5 ≤ M≤ 100	10 ≤ d ≤ 20	0.2 ≤ k ≤ 1	1 ≤ x ≤ 10	0 < $\eta_{rec,d}$ < 80	0 < p < 80
Mobile A/C	0.5 ≤ M ≤ 1.5	9 ≤ d ≤ 16	0.2 ≤ k ≤ 0.5	10 ≤ x ≤ 20[5]	0 < $\eta_{rec,d}$ < 50	0 < p < 50

[1] Based on information contained in UNEP RTOC Reports (UNEP-RTOC, 1999; UNEP-RTOC, 2003)
[2, 3] Lower value for developed countries and higher value for developing countries
[4] The lower threshold (0%) highlights that there is no recovery in some countries.
[5] Schwarz and Harnisch (2003) estimates leakage rates of 5.3% to 10.6%; these rates apply only to second generation mobile air conditioners installed in European models in 1996 and beyond.

Source: 2006 IPCC Guidelines

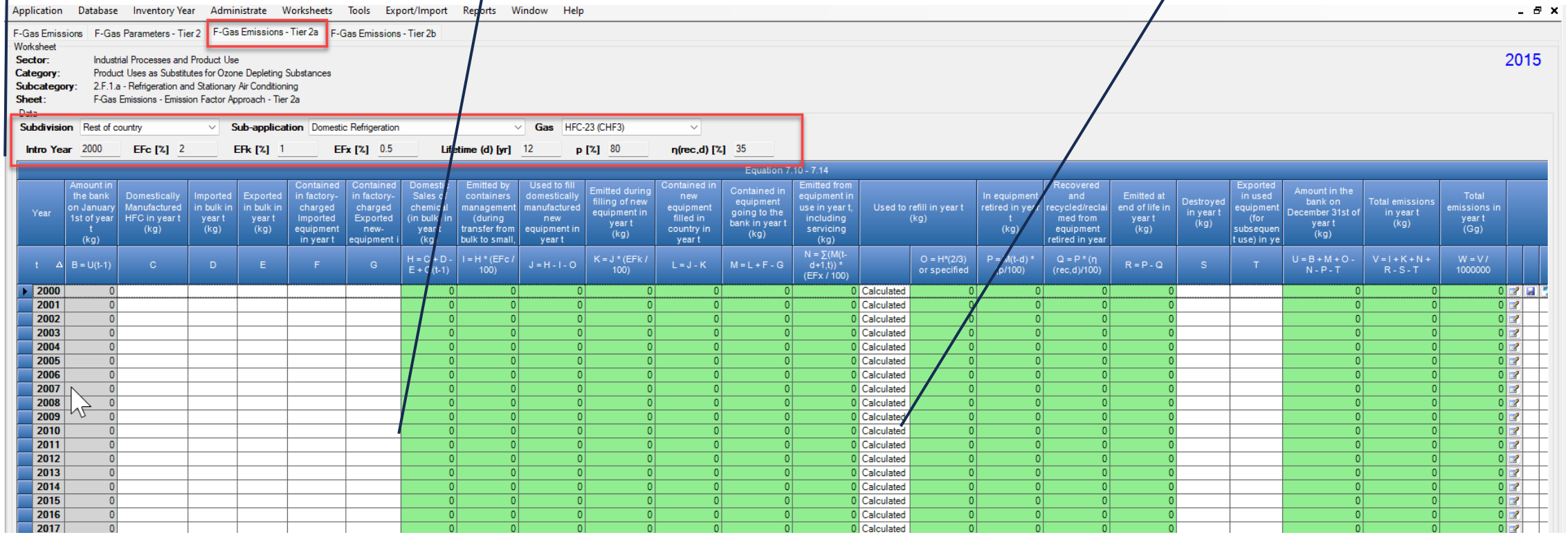
2F1: Tier 2a – AD

Once all parameters are entered in <F-gas Parameters-Tier 2>, the times series data entry grid appears in worksheet <F-Gas Emissions-Tier 2a>, ready for AD entry.

Selected parameters/ EFs visible here

White cells = data input
Green cells = calculated

Choice of calculated /or data input (specified)



2F1: Example for Tier 2a

1. Note data added in "Parameters".

2. System automatically calculated servicing. If amount known, select "Specified" and add data .

3. Note that these activities were not known to occur. In IPCC software, this can be left blank. The Software is an estimation tool, not a reporting tool, so notation keys such as "NO" not accepted.

4. System calculates emissions in kg and Gg.

F-Gas Emissions | F-Gas Parameters - Tier 2 | F-Gas Emissions - Tier 2a | F-Gas Emissions - Tier 2b

Worksheet

Sector: Industrial Processes and Product Use
Category: Product Uses as Substitutes for Ozone Depleting Substances
Subcategory: 2.F.1.a - Refrigeration and Stationary Air Conditioning
Sheet: F-Gas Emissions - Emission Factor Approach - Tier 2a

2015

Data

Subdivision Capital city | **Sub-application** Domestic Refrigeration | **Gas** HFC-134a (CH2FCF3)

Intro Year 2000 | **EFc [%]** 2 | **EFk [%]** 0.5 | **EFx [%]** 0.25 | **Lifetime (d) [yr]** 12 | **p [%]** 80 | **η(rec,d) [%]** 35

Equation 7.10 7.11

Year	Amount in the bank on January 1st of year t (kg)	Domestically Manufactured HFC in year t (kg)	Imported in bulk in year t (kg)	Exported in bulk in year t (kg)	Contained in factory-charged Imported equipment in year t	Contained in factory-charged Exported new-equipment i	Domestic Sales of chemical (in bulk) in year t (kg)	Emitted by containers management (during transfer from bulk to small,	Used in equipment manufactured new equipment in year t	Emitted during filling of new equipment in year t (kg)	Contained in new equipment filled in country in year t	Contained in equipment going to the bank in year t (kg)	Emitted from equipment in use in year t, including servicing (kg)	Used to refill in year t (kg)	In equipment retired in year t (kg)	Recovered and recycled/reclaimed from equipment retired in year	Emitted at end of life in year t (kg)	Destroyed in year t (kg)	Exported in used equipment (for subsequent use) in year t	Amount in the bank on December 31st of year t (kg)	Total emissions in year t (kg)	Total emissions in year t (Gg)
t Δ	B = U(t-1)	C	D	E	F	G	H = C + D - E + Q(t-1)	I = H * (EFc / 100)	J = H - I - O	K = J * (EFk / 100)	L = J - K	M = L + F - G	N = ∑(M(t-d+1,t)) * (EFx / 100)		O = H*(2/3) or specified	P = M(t-d) * (p/100)	Q = P * (η (rec,d)/100)	R = P - Q	S	T	U = B + M + O - N - P - T	V = I + K + N + R - S - T	W = V / 1000000
2000	0		3.7		0.7		3.7	0.074	1.15933	0.0058	1.15354	1.85354	0.00463	Calculated	2.46667	0	0	0			4.31557	0.08443	0
2001	4.31557		3.8		0.8		3.8	0.076	1.19067	0.00595	1.18471	1.98471	0.0096	Calculated	2.53333	0	0	0			8.82402	0.09155	0
2002	8.82402		3.9		0.8		3.9	0.078	1.222	0.00611	1.21589	2.01589	0.01464	Calculated	2.6	0	0	0			13.42528	0.09875	0
2003	13.42528		3.9		0.8		3.9	0.078	1.222	0.00611	1.21589	2.01589	0.01968	Calculated	2.6	0	0	0			18.02149	0.10379	0
2004	18.02149		4		0.8		4	0.08	1.25333	0.00627	1.24707	2.04707	0.02479	Calculated	2.66667	0	0	0			22.71043	0.11106	0
2005	22.71043		4.1		0.8		4.1	0.082	1.28467	0.00642	1.27824	2.07824	0.02999	Calculated	2.73333	0	0	0			27.49202	0.11841	0
2006	27.49202		4.2		0.8		4.2	0.084	1.316	0.00658	1.30942	2.10942	0.03526	Calculated	2.8	0	0	0			32.36618	0.12584	0
2007	32.36618		4.3		0.9		4.3	0.086	1.34733	0.00674	1.3406	2.2406	0.04086	Calculated	2.86667	0	0	0			37.43258	0.1336	0
2008	37.43258		4.4		0.9		4.4	0.088	1.37867	0.00689	1.37177	2.27177	0.04654	Calculated	2.93333	0	0	0			42.59114	0.14144	0
2009	42.59114		4.4		0.9		4.4	0.088	1.37867	0.00689	1.37177	2.27177	0.05222	Calculated	2.93333	0	0	0			47.74403	0.14712	0
2010	47.74403		4.5		0.9		4.5	0.09	1.41	0.00705	1.40295	2.30295	0.05798	Calculated	3	0	0	0			52.989	0.15503	0
2011	52.989		4.6		0.9		4.6	0.092	1.44133	0.00721	1.43413	2.33413	0.06381	Calculated	3.06667	0	0	0			58.32597	0.16302	0
2012	58.32597		4.7		0.9		4.7	0.094	1.47267	0.00736	1.4653	2.3653	0.06509	Calculated	3.13333	1.48283	0.51899	0.96384			62.27669	1.1303	0
2013	62.27669		4.8		1		5.31899	0.10638	1.66662	0.00833	1.65828	2.65828	0.06678	Calculated	3.54599	1.58777	0.55572	1.03205			66.82642	1.21354	0
2014	66.82642		4.9		1		5.45572	0.10911	1.70946	0.00855	1.70091	2.70091	0.06849	Calculated	3.63715	1.61271	0.56445	1.04826			71.48327	1.23442	0
2015	71.48327		5		1		5.56445	0.11129	1.74353	0.00872	1.73481	2.73481	0.07029	Calculated	3.70963	1.61271	0.56445	1.04826			76.24471	1.23856	0
2016	76.24471		5.1		1		5.66445	0.11329	1.77486	0.00887	1.76599	2.76599	0.07209	Calculated	3.7763	1.63765	0.57318	1.06447			81.07726	1.25872	0
2017	81.07726		5.2		1		5.77318	0.11546	1.80893	0.00904	1.79988	2.79988	0.07389	Calculated	3.84879	1.66259	0.58191	1.08069			85.98945	1.27908	0
2018	85.98945		5.3		1.1		5.88191	0.11764	1.843	0.00921	1.83378	2.93378	0.07595	Calculated	3.92127	1.68754	0.59064	1.0969			91.08101	1.2997	0
2019	91.08101		5.4		1.1		5.99064	0.11981	1.87707	0.00939	1.86768	2.96768	0.07777	Calculated	3.99376	1.79248	0.62737	1.16511			96.17221	1.37208	0
2020	96.17221		5.5		1.1		6.12737	0.12255	1.91991	0.0096	1.91031	3.01031	0.07961	Calculated	4.08491	1.81742	0.6361	1.18132			101.3704	1.39308	0
2021	101.3704		5.6		1.1		6.2361	0.12472	1.95398	0.00977	1.94421	3.04421	0.08155	Calculated	4.1574	1.81742	0.6361	1.18132			106.67304	1.39736	0
2022	106.67304		5.7		1.1		6.3361	0.12672	1.98531	0.00993	1.97538	3.07538	0.08348	Calculated	4.22406	1.84236	0.64483	1.19753			112.04665	1.41766	0

2.F.1 Refrigeration and Air Conditioning

Tier 2b

2F1: Tier 2b

EQUATION 7.9
DETERMINATION OF REFRIGERANT EMISSIONS BY MASS BALANCE

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

- **Annual Sales of New Refrigerant:** the amount of a chemical introduced in a given year. It includes all chemical used to fill or refill equipment, whether the chemical is charged into equipment at the factory, charged into equipment after installation, or used to recharge equipment at servicing. It does not include recycled or reclaimed chemical.

- **Total Charge of New Equipment:** the sum of the full charges of all the new equipment that is sold in a given year. It includes both the chemical required to fill equipment in the factory and the chemical required to fill the equipment after installation. It does not include charging emissions or chemical used to recharge equipment at servicing.

- **Original Total Charge of Retiring Equipment:** the sum of the full charges of all the retiring equipment decommissioned in a given year. It assumes that the equipment will have been serviced right up to its decommissioning and will therefore contain its original charge.

- **Amount of Intentional Destruction:** quantity of the chemical duly destroyed by a recognised destruction technology.

2F1: Tier 2b

The Tier 2b worksheet will be blank until all EFs and Parameters are added in worksheet <F-gas Parameters – Tier 2>

F-Gas Emissions | F-Gas Parameters - Tier 2 | F-Gas Emissions - Tier 2a | F-Gas Emissions - Tier 2b

Worksheet

Sector: Industrial Processes and Product Use
Category: Product Uses as Substitutes for Ozone Depleting Substances
Subcategory: 2.F.1.a - Refrigeration and Stationary Air Conditioning
Sheet: F-Gas Emissions - Mass Balance Approach - Tier 2b

2015

Data

Subdivision | **Sub-application** | **Gas**

Intro Year | **Lifetime (d) [yr]** | **η(rec,d) [%]** | **Stockpile**

Equation 7.9

Year	Domestically Manufactured HFC in year t (kg)	Imported in bulk in year t (kg)	Exported in bulk in year t (kg)	Contained in factory-charged Imported equipment in year t	Contained in factory-charged Exported new -equipment in year t	Domestic Sales of new chemical in year t (kg)	To / from stockpile (kg)	Used in year t to fill new equipment not factory-charged (kg)	Used in year t to fill new equipment factory-charged (kg)	Total Charge in new-equipment in year t (kg)	Used in year t -d to fill new equipment not factory-charged (kg)	Used in year t -d to fill new equipment factory-charged (kg)	Original Total Charge in year t-d of Equipment Retiring in year t	Recov recycled/re equipment r (k
t Δ	B	C	D	E	F	G = B + C - D + E - F								

F-Gas Emissions | F-Gas Parameters - Tier 2 | F-Gas Emissions - Tier 2a | F-Gas Emissions - Tier 2b

Worksheet

Sector: Industrial Processes and Product Use
Category: Product Uses as Substitutes for Ozone Depleting Substances
Subcategory: 2.F.1.a - Refrigeration and Stationary Air Conditioning
Sheet: F-Gas Parameters - Tier 2

2015

Data

F-Gases Manager

Subdivision

- Capital city
- Rest of country

Sub-application

- Domestic Refrigeration

Chemical	Tier	Year of Introduction	Emission factor for containers management (%/yr)	Emission factor for filling (production/manufacturing) of new equipment (% initial charge/yr)	Emission factor for equipment operation (leakage/servicing) (% initial charge/yr)	Lifetime of equipment (years)	Share of initial charge remaining at the end of life (%)	Recovery efficiency of charge (to be reclaimed/recycled) remaining at end of life in retired equipment (%)		UNFCCC CRT Confidentiality			
		t(start)	EFc	EFk	EFx	d	p	η(rec,d)					
HFC-23 (CHF3)	Tier 2a	2000	2	1	0.5	15	70	80					
HFC-32 (CH2F2)	Tier 2b	2000				15		80					

Sub-application

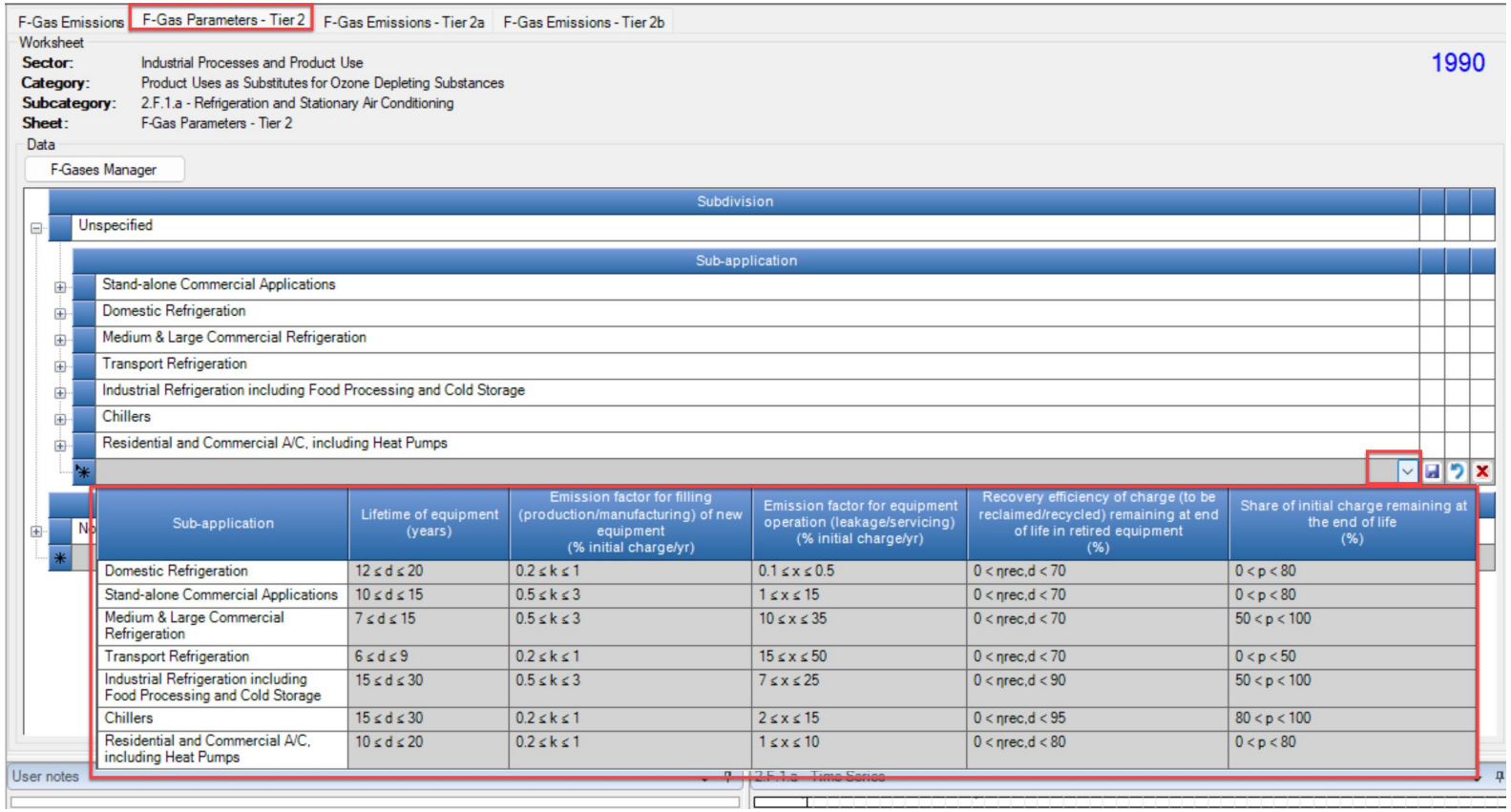
Subdivision

2F1: Tier 2b – parameters

Only two default parameters need to be selected:

i. lifetime

ii. recovery efficiency



Sub-application	Lifetime of equipment (years)	Emission factor for filling (production/manufacturing) of new equipment (% initial charge/yr)	Emission factor for equipment operation (leakage/servicing) (% initial charge/yr)	Recovery efficiency of charge (to be reclaimed/recycled) remaining at end of life in retired equipment (%)	Share of initial charge remaining at the end of life (%)
Domestic Refrigeration	12 ≤ d ≤ 20	0.2 ≤ k ≤ 1	0.1 ≤ x ≤ 0.5	0 < ηrec,d < 70	0 < p < 80
Stand-alone Commercial Applications	10 ≤ d ≤ 15	0.5 ≤ k ≤ 3	1 ≤ x ≤ 15	0 < ηrec,d < 70	0 < p < 80
Medium & Large Commercial Refrigeration	7 ≤ d ≤ 15	0.5 ≤ k ≤ 3	10 ≤ x ≤ 35	0 < ηrec,d < 70	50 < p < 100
Transport Refrigeration	6 ≤ d ≤ 9	0.2 ≤ k ≤ 1	15 ≤ x ≤ 50	0 < ηrec,d < 70	0 < p < 50
Industrial Refrigeration including Food Processing and Cold Storage	15 ≤ d ≤ 30	0.5 ≤ k ≤ 3	7 ≤ x ≤ 25	0 < ηrec,d < 90	50 < p < 100
Chillers	15 ≤ d ≤ 30	0.2 ≤ k ≤ 1	2 ≤ x ≤ 15	0 < ηrec,d < 95	80 < p < 100
Residential and Commercial A/C, including Heat Pumps	10 ≤ d ≤ 20	0.2 ≤ k ≤ 1	1 ≤ x ≤ 10	0 < ηrec,d < 80	0 < p < 80

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 ≤ M ≤ 0.5	12 ≤ d ≤ 20	0.2 ≤ k ≤ 1	0.1 ≤ x ≤ 0.5	0 < $\eta_{rec,d}$ < 70	0 < p < 80
Stand-alone Commercial Applications	0.2 ≤ M≤ 6	10 ≤ d ≤ 15	0.5 ≤ k ≤ 3	1 ≤ x ≤ 15	0 < $\eta_{rec,d}$ < 70	0 < p < 80
Medium & Large Commercial Refrigeration	50 ≤ M ≤ 2000	7 ≤ d ≤ 15	0.5 ≤ k ≤ 3	10 ≤ x ≤ 35	0 < $\eta_{rec,d}$ < 70	50 < p < 100
Transport Refrigeration	3 ≤ M ≤ 8	6 ≤ d ≤ 9	0.2 ≤ k ≤ 1	15 ≤ x ≤ 50	0 < $\eta_{rec,d}$ < 70	0 < p < 50
Industrial Refrigeration including Food Processing and Cold Storage	10 ≤ M ≤ 10,000	15 ≤ d ≤ 30	0.5 ≤ k ≤ 3	7 ≤ x ≤ 25	0 < $\eta_{rec,d}$ < 90	50 < p < 100
Chillers	10 ≤ M≤ 2000	15 ≤ d ≤ 30	0.2 ≤ k ≤ 1	2 ≤ x ≤ 15	0 < $\eta_{rec,d}$ < 95	80 < p < 100
Residential and Commercial A/C, including Heat Pumps	0.5 ≤ M≤ 100	10 ≤ d ≤ 20	0.2 ≤ k ≤ 1	1 ≤ x ≤ 10	0 < $\eta_{rec,d}$ < 80	0 < p < 80
Mobile A/C	0.5 ≤ M ≤ 1.5	9 ≤ d ≤ 16	0.2 ≤ k ≤ 0.5	10 ≤ x ≤ 20[5]	0 < $\eta_{rec,d}$ < 50	0 < p < 50

[1] Based on information contained in UNEP RTOC Reports (UNEP-RTOC, 1999; UNEP-RTOC, 2003)
[2, 3] Lower value for developed countries and higher value for developing countries
[4] The lower threshold (0%) highlights that there is no recovery in some countries.
[5] Schwarz and Harnisch (2003) estimates leakage rates of 5.3% to 10.6%; these rates apply only to second generation mobile air conditioners installed in European models in 1996 and beyond.

Source: 2006 IPCC Guidelines

2F1: Tier 2b – AD

Once all parameters are entered in <F-gas Parameters-Tier 2>, the times series data entry grid appears in worksheet <F-Gas Emissions-Tier 2b>, ready for AD entry.

F-Gas Emissions | F-Gas Parameters - Tier 2 | F-Gas Emissions - Tier 2a | F-Gas Emissions - Tier 2b

Worksheet

Sector: Industrial Processes and Product Use
Category: Product Uses as Substitutes for Ozone Depleting Substances
Subcategory: 2.F.1.a - Refrigeration and Stationary Air Conditioning
Sheet: F-Gas Emissions - Mass Balance Approach - Tier 2b

2015

Data

Subdivision Rest of country **Sub-application** Domestic Refrigeration **Gas** HFC-32 (CH2F2)

Intro Year 2000 **Lifetime (d) [yr]** 15 **n(rec,d) [%]** 80 **Stockpile** 157

Equation 7.9

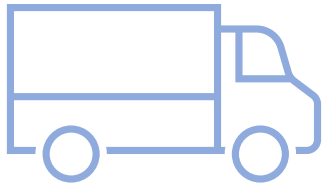
Year	Domestically Manufactured HFC in year t (kg)	Imported in bulk in year t (kg)	Exported in bulk in year t (kg)	Contained in factory-charged Imported equipment in year t (kg)	Contained in factory-charged Exported new-equipment in year t (kg)	Domestic Sales of new chemical in year t (kg)	To / from stockpile (kg)	Used in year t to fill new equipment not factory-charged (kg)	Used in year t to fill new equipment factory-charged (kg)	Total Charge in new-equipment in year t (kg)	Used in year t-d to fill new equipment not factory-charged (kg)	Used in year t-d to fill new equipment factory-charged (kg)	Original Total Charge in year t-d of Equipment Retiring in year t (kg)	Recovered and recycled/reclaimed from equipment retired in year t (kg)		Destroyed in year t (kg)	Exported in used equipment in year t (kg)	Total emissions in year t (kg)	Total emissions in year t (Gg)	Information for UNFCCC CRT Bank (kg)
t	B	C	D	E	F	G = B + C - D + E - F	S	H	I	J = H + I	K = H(t-d)	L = I(t-d)	M = K + L		N = M * (η (rec,d)/100) or specified	O	P	Q = (G - S) - J + M - N - O - P	R = Q / 1000000	X = ∑(J(t-d+1,t)) - Mt
2000	1000			100		1100	25	1000		1000	0	0	0	Calcul...	0		25	50	0.00005	1000
2001	1100			100		1200	22	1000		1000	0	0	0	Calcul...	0		25	153	0.00015	2000
2002	1211			100		1311	0	1000		1000	0	0	0	Calcul...	0		30	281	0.00028	3000
2003	2000			100		2100	0	1000		1000	0	0	0	Calcul...	0		30	1070	0.00107	4000
2004	3000			100		3100	0	1000		1000	0	0	0	Calcul...	0		40	2060	0.00206	5000
2005	1000			100		1100	0	1000		1000	0	0	0	Calcul...	0			100	0.0001	6000
2006	2000			100		2100	0	1000		1000	0	0	0	Calcul...	0		24	1076	0.00108	7000
2007	1600			100		1700	0	1000		1000	0	0	0	Calcul...	0		56	644	0.00064	8000
2008	2000			100		2100	0	1000		1000	0	0	0	Calcul...	0		35	1065	0.00107	9000
2009	4000			100		4100	0	1000		1000	0	0	0	Calcul...	0		30	3070	0.00307	10000
2010	1000			100		1100	0	1000		1000	0	0	0	Calcul...	0			100	0.0001	11000
2011	1500			100		1600	100	1000		1000	0	0	0	Calcul...	0			500	0.0005	12000
2012	2000			100		2100	10	1000		1000	0	0	0	Calcul...	0		100	990	0.00099	13000
2013	1000			100		1100	0	1000		1000	0	0	0	Calcul...	0			100	0.0001	14000
2014	900	90		100		1090	0	1000		1000	0	0	0	Calcul...	0			90	0.00009	15000
2015	1000	100		100		1200	0	1200		1200	1000	0	1000	Calcul...	800	100		100	0.0001	14200
2016	1000	100		1000		2100	0	1200		1200	1000	0	1000	Calcul...	800	25		1075	0.00108	14400
2017	1590	25		900		2515	0	1200		1200	1000	0	1000	Calcul...	800	100		1415	0.00142	14600
2018	2000	1000		800		3800	0	1200		1200	1000	0	1000	Calcul...	800	200		2600	0.0026	14800
2019	233	25		900		1158	0	1200		1200	1000	0	1000	Calcul...	800			158	0.00016	15000
2020	1000	25		1000		2025	0	1200		1200	1000	0	1000	Calcul...	800			1025	0.00103	15200
2021						0				0	1000	0	1000	Calcul...	800			200	0.0002	14200
2022						0				0	1000	0	1000	Calcul...	800			200	0.0002	13200

Uncertainties

2F1: Note on Interoperability

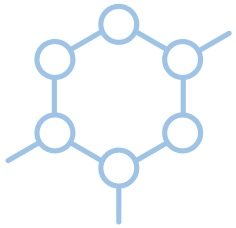
Sub-application per IPCC	Mapping to CRT
Domestic Refrigeration	Maps to domestic refrigeration in CRT
Medium & Large Commercial Refrigeration	Maps to commercial refrigeration in CRT
Standalone commercial applications	
Chillers	
Industrial Refrigeration, incl. food processing and cold storage	Maps to industrial refrigeration in CRT
Transport Refrigeration	Maps to transport refrigeration in CRT
Residential and commercial A/C, incl heat pumps	Maps to stationary air conditioning in CRT
User defined sub-applications	

Conclusion









IPCC Inventory Software:

- Is a valuable tool to aid in emissions calculations for IPPU sector, which has a variety of industries following a variety of methods.
- Accommodates multiple tiers relying on different types of AD (e.g. production versus consumption).
- Visualizes the CRT, allowing users to see how data will appear in the CRT. Allows for addition of notation keys, including explanations, and method/EF used.
- Allows users to designate information, particularly AD, as confidential. User responsibility to understand how confidentiality works.

Demonstration Example

2F1 – Refrigeration and Air conditioning – Tier 1

HFC-134a and HFC-152a have been used as refrigerants in Country X since 2015 and 2016 respectively.
The data on production, import and export in terms of mass of HFC-134a are shown in the table below as well as growth rate in new equipment sales, assumed equipment lifetime, emission factor from installed base and % of gas destroyed at end of life.

Estimate emissions of HFC-134a and HFC-152a from refrigeration in Country X in 2020.

<HFC-134a (CH_2FCF_3)>

Introduction Year	2015	**Assumed Equipment Lifetime**	15 years
Growth Rate in New Equipment Sales	3.00%	**Emission Factor from Installed Base**	4.00%
% of Gas Destroyed at End of Life	15.00%		

(tonne)

Years	2014	2015	2016	2017	2018	2019	2020
Production	0	24	40	69	90	147	220
Export	0	0	0	12	24	34	68
Import	0	0	0	0	0	0	0

<HFC-152a (CH_3CHF_2) >

Introduction Year	2016	**Assumed Equipment Lifetime**	15 years
Growth Rate in New Equipment Sales	4.00%	**Emission Factor from Installed Base**	3.00%
% of Gas Destroyed at End of Life	0.00%		

(tonne)

Years	2014	2015	2016	2017	2018	2019	2020
Production							246
Export							34
Import							0

Data are not available for these years…

FOR YOUR ATTENTION

STAY IN TOUCH

ipcc-nggip.iges.or.jp

nggip-tsu@iges.or.jp

STAY CONNECTED

ipcc_ch

ipcc

@ipcc

ipcc