Estimation Methodology for RACs in the 2006 IPCC Guidelines and 2019 Refinement

The 17th Workshop on GHG Inventories in Asia (WGIA17)

30 July - 2 August 2019, Singapore

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INTERGOVERNMENTAL PANEL ON climate change

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Guidance in the 2006 IPCC Guidelines

Refrigeration and Air Conditioning (RAC)

- One of the major application areas of ODS substitutes
- May be classified into 6 sub-application domains or categories:
  i. Domestic (i.e., household) refrigeration;
  ii. Commercial refrigeration including different types of equipment, from vending machines to centralised refrigeration systems in supermarkets;
  iii. Industrial processes including chillers, cold storage, and industrial heat pumps used in the food, petrochemical and other industries;
  iv. Transport refrigeration including equipment and systems used in refrigerated trucks, containers, reefers, and wagons;
  v. Stationary air conditioning including air-to-air systems, heat pumps, and chillers for building and residential applications; and
  vi. Mobile air-conditioning systems used in passenger cars, truck cabins, buses, and trains

F-gases used as refrigerant in RAC

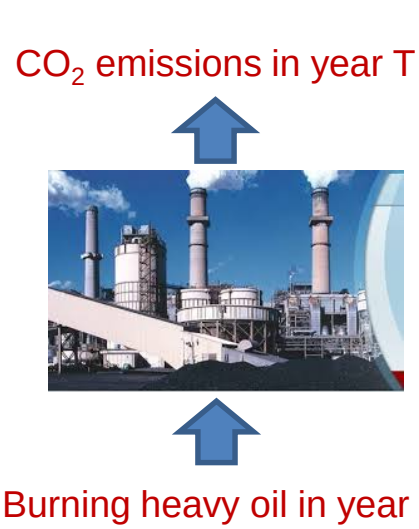
- A large number of blends containing HFCs and/or PFCs are being used.
- The most common of these blends are shown in Table 7.8 in Chapter 7, Vol.3 of 2006 IPCC Guidelines.

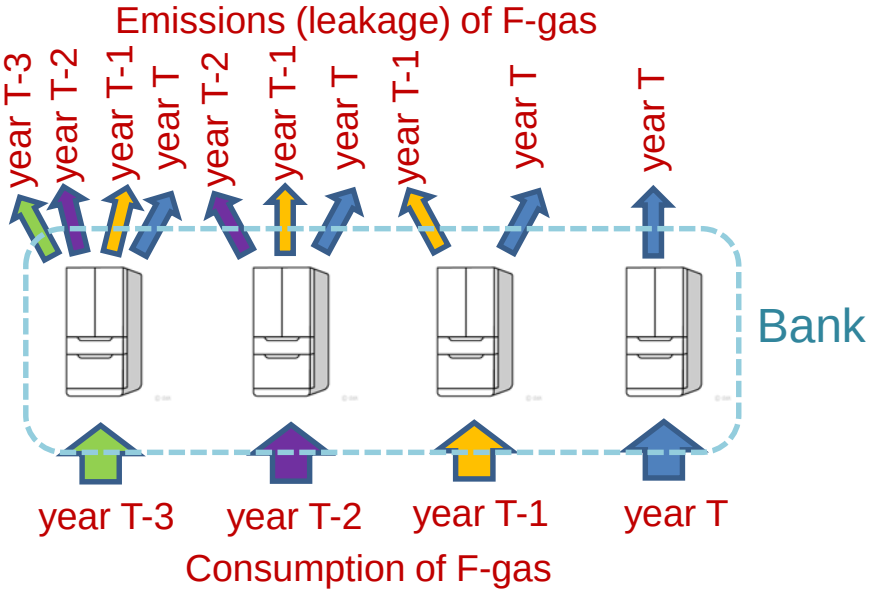
TABLE 7.8
BLENDS (MANY CONTAINING HFCS AND/OR PFCS)

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)

Difficulty in estimating emissions

- Considerable time lag between consumption and emission
  - A chemical placed in new products slowly leaks out over many years.





- Hurdles for collecting necessary data/information
  - Cooperation is required of various players including private companies.
  - Care needs to be taken in dealing with refrigerant blends.
  - Trade of equipment needs to be monitored.

"Bank"

Total amount of substances contained in existing equipment not yet released to the atmosphere

$$Bank_y = Bank_{y-1} + Addition_y - Removal_y$$

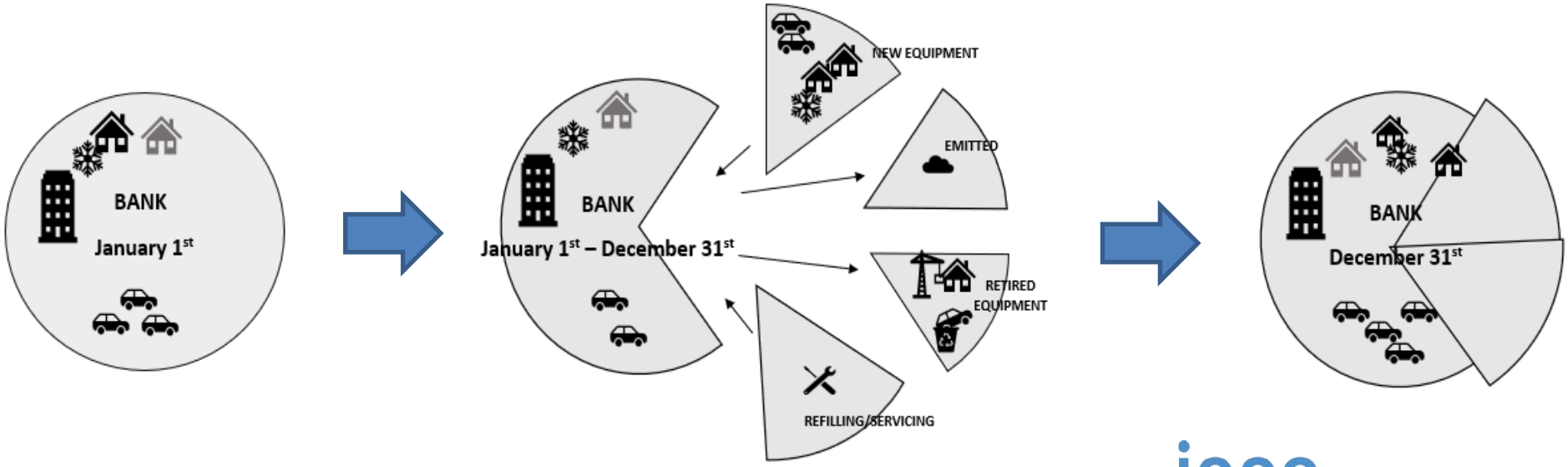
Where:

$Bank_y$ = Refrigerant bank on December 31st of year y, kg

$Bank_{y-1}$ = Refrigerant bank on December 31st of year y-1/January 1st of year y, kg

$Additon_y$ = Addition of new substances year y, kg

$Removal_y$ = Removal of substances exported, emitted or destroyed year y, kg



Methods to estimate emissions

- Three methods are provided in the *2006 IPCC Guidelines*.
  - Tier 1: Use of spreadsheet calculation tool
  - Tier 2a: Emission factor approach
  - Tier 2b: Mass balance approach
- Which tier should be used?
  - Follow the decision tree in Figure 7.6 in Chapter 7, Vol. 3
- If RAC is a *key category*, either Tier 2a or 2b should be used.
- Even if RAC is not a *key category*, inventory compilers may conclude Tier 2 provides more value with little extra work as compared to Tier 1.

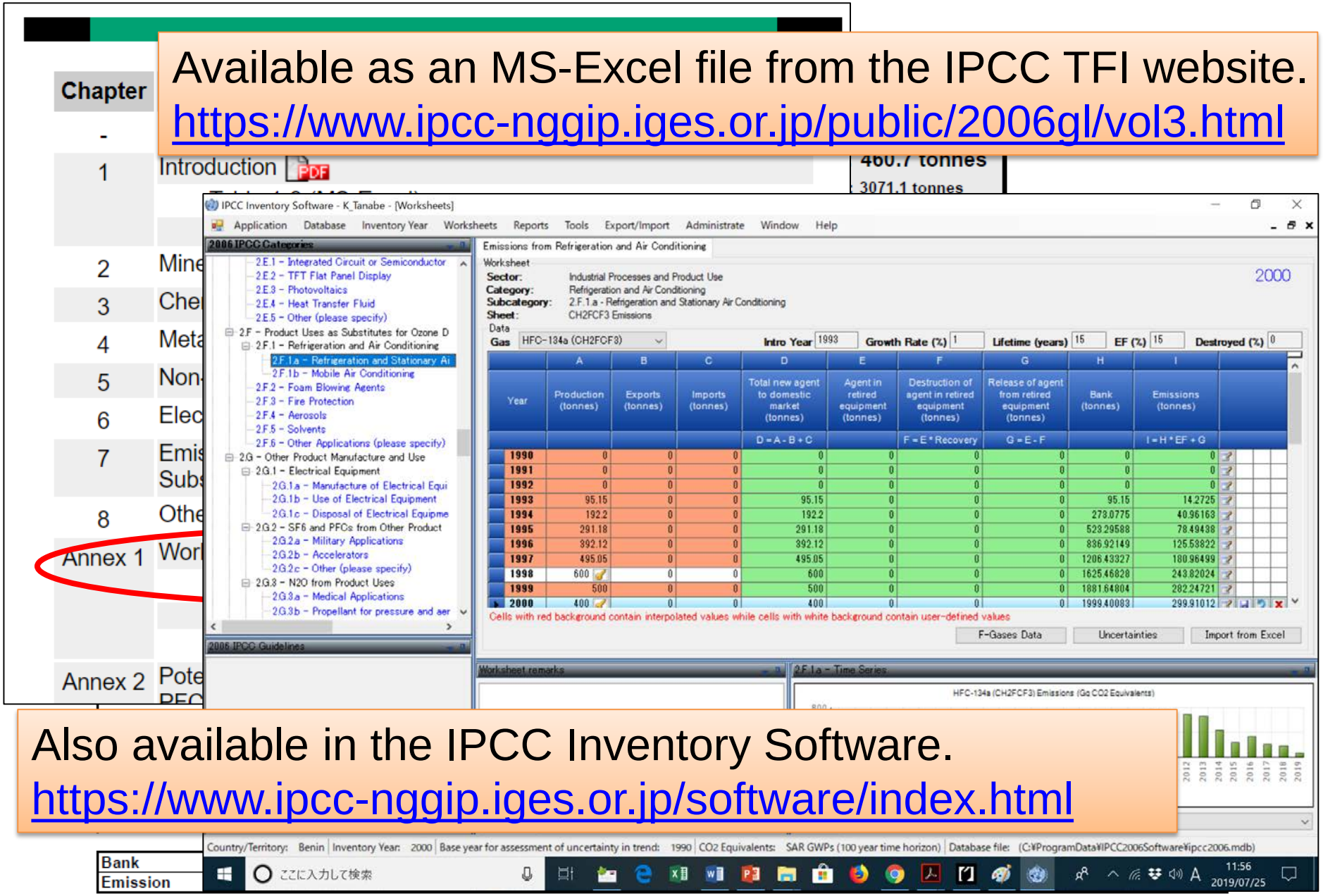
Tier 1 – spreadsheet calc tool

- Tier 1 method can be used if you have at least the data/information on:
  - Year of introduction of the refrigerant
  - Domestic production of the refrigerant in the current year
  - Imports of the refrigerant in the current year
  - Exports of the refrigerant in current year
  - Growth rate of sales of equipment that uses the refrigerant

- Empirical assumptions are used to fill in the data gaps to enable estimation of emissions.
- However, it is still necessary to have an accurate assessment of net consumption activity data.

Tier 1 – spreadsheet calc tool

Available as an MS-Excel file from the IPCC TFI website.
https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol3.html



Also available in the IPCC Inventory Software.
https://www.ipcc-nggip.iges.or.jp/software/index.html

Tier 2a – Emission Factor Approach

- Emissions are calculated separately for four stages:
  - $E_{containers,t}$ = emissions related to the management of refrigerant containers
  - $E_{charge,t}$ = emissions related to the refrigerant charge: connection and disconnection of the refrigerant container and the new equipment to be charged
  - $E_{lifetime,t}$ = annual emissions from the banks of refrigerants associated with the six sub-applications during operation (fugitive emissions and ruptures) and servicing
  - $E_{end\text{-}of\text{-}life,t}$ = emissions at system disposal

EQUATION 7.10
SUMMARY OF SOURCES OF EMISSIONS

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

Tier 2a – Emission Factor Approach

➢ Refrigerant management of containers

EQUATION 7.11
SOURCES OF EMISSIONS FROM MANAGEMENT OF CONTAINERS

$$E_{containers,t} = RM_t \bullet \frac{c}{100}$$

Where:

$E_{containers, t}$ = emissions from all HFC containers in year *t*, kg

RM_t = HFC market for new equipment and servicing of all refrigeration application in year *t*, kg

c = emission factor of HFC container management of the current refrigerant market, percent

➢ Refrigerant charge emissions of new equipment

EQUATION 7.12
SOURCES OF EMISSIONS WHEN CHARGING NEW EQUIPMENT

$$E_{charge,t} = M_t \bullet \frac{k}{100}$$

Where:

$E_{charge, t}$ = emissions during system manufacture/assembly in year *t*, kg

M_t = amount of HFC charged into new equipment in year *t* (per sub-application), kg

k = emission factor of assembly losses of the HFC charged into new equipment (per sub-application), percent

Note: the emissions related to the process of connecting and disconnecting during servicing are covered in Equation 7.13.

Tier 2a – Emission Factor Approach

➢ Emissions during lifetime (operation and servicing)

EQUATION 7.13
SOURCES OF EMISSIONS DURING EQUIPMENT LIFETIME

$$E_{lifetime,\,t} = B_t \bullet \frac{x}{100}$$

Where:

$E_{lifetime,\,t}$ = amount of HFC emitted during system operation in year *t*, kg

B_t = amount of HFC banked in existing systems in year *t* (per sub-application), kg

x = annual emission rate (i.e., emission factor) of HFC of each sub-application bank during operation, accounting for average annual leakage and average annual emissions during servicing, percent

➢ Emissions at end-of-life

EQUATION 7.14
EMISSIONS AT SYSTEM END-OF-LIFE

$$E_{end-of-life,\,t} = M_{t-d} \bullet \frac{p}{100} \bullet (1 - \frac{\eta_{rec,\,d}}{100})$$

Where:

$E_{end\text{-}of\text{-}life,\,t}$ = amount of HFC emitted at system disposal in year *t*, kg

$M_{t\text{-}d}$ = amount of HFC initially charged into new systems installed in year (*t*-*d*), kg

p = residual charge of HFC in equipment being disposed of expressed in percentage of full charge, percent

$\eta_{rec,d}$ = recovery efficiency at disposal, which is the ratio of recovered HFC referred to the HFC contained in the system, percent

Tier 2a – Emission Factor Approach

- Default emission factors are provided in Table 7.9.

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	$0.05 \le M \le 0.5$	$12 \le d \le 20$	$0.2 \le k \le 1$	$0.1 \le x \le 0.5$	$0 < \eta_{rec,d} < 70$	$0 < p < 80$
Stand-alone Commercial Applications	$0.2 \le M \le 6$	$10 \le d \le 15$	$0.5 \le k \le 3$	$1 \le x \le 15$	$0 < \eta_{rec,d} < 70$	$0 < p < 80$
Medium & Large Commercial Refrigeration	$50 \le M \le 2000$	$7 \le d \le 15$	$0.5 \le k \le 3$	$10 \le x \le 35$	$0 < \eta_{rec,d} < 70$	$50 < p < 100$
Transport Refrigeration	$3 \le M \le 8$	$6 \le d \le 9$	$0.2 \le k \le 1$	$15 \le x \le 50$	$0 < \eta_{rec,d} < 70$	$0 < p < 50$
Industrial Refrigeration	$10 < M <$				$0 < \eta_{rec,d} <$	$50 < p <$

Tier 2b – Mass Balance Approach

EQUATION 7.9
DETERMINATION OF REFRIGERANT EMISSIONS BY MASS BALANCE

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

- Does not rely on emission factors.
- Relies on a knowledge of the annual sales of refrigerant, refrigerant destroyed and any changes in equipment stock that occur on a sub-application basis.
- May underestimate emissions when equipment stocks are growing, because there is a lag between the time the emissions occur and the time they are detected (through equipment servicing).

Refinements made in the 2019 Refinement

No change in methodology

- Methodological framework remains unchanged.
  - No refinement in the Tier 1 spreadsheet calculation tool.
  - No refinement in the Tier 2a equations.
  - No refinement in the Tier 2b equations.
  - No refinement in the decision tree.

More helpful guidance added

- "Cook-book" style guidance as regards:
  - How to implement Tier 1 and Tier 2a in a few simple steps
    - ✓For Tier 2a, the spreadsheet "Calculation example for 2F1 (Tier 2)" is provided.
  - Basic elements of an HFC emission inventory for RAC
    - ✓Explanation about the "bank" as well as the flow into and out of the bank
  - How to build the "bank"
- Information on common data sources
- Examples of national studies on emission rates for stationary RAC systems

F4

Country	
Equipment type (sub-application)	
Chemical or blend	
Current Year	
Year of Introduction	

Emission factor for filling (production/ manufacturing) of new equipment (per cent per year)

	Equal to amount in bank on 31st of December the previous year						*A+B-C+(N previous year)*	*F-K*	*G*emission factor*	*G-H*	*I+D-E*	
Year	Amount in the bank on January 1st (kg)	A. Produced in country (kg)	B. Imported in bulk (kg)	C. Exported in bulk (kg)	D. Imported in equipment (kg)	E. Exported in new equipment (kg)	F.Domestic sales of HFCs in bulk (kg)	G. Used for filling of new equipment (kg)	H. Emitted during filling of new equipmet (kg)	I. Contained in new equipment filled in country (kg)	J. Contained in new eqipment going to the bank (kg)	K. refillin vicin
1989	0.00						0.00	0.00	0.00	0.00	0.00	
1990	0.00						0.00	0.00	0.00	0.00	0.00	
1991	0.00						0.00	0.00	0.00	0.00	0.00	
1992	0.00						0.00	0.00	0.00	0.00	0.00	
1993	0.00						0.00	0.00	0.00	0.00	0.00	

Updated data/information included

- Updated default emission factors for Tier 2a method (updated Table 7.9)

TABLE 7.9 (UPDATED)
DEFAULT ESTIMATES 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)**
			At Time of Charge	**Annual loss, Operating Lifetime**	**Recovery Efficiency[4]**	**Initial Charge Remaining**
Domestic Refrigeration	$0.05 \le M \le 0.5$	$12 \le d \le 20$	$0.2 \le k \le 1$	$0.1 \le x \le 0.5$	$0 < \eta_{rec,d} < 70$	$0 < p < 80$
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Transport	$3 \le M \le 8$	$6 \le d \le 9$	$0.2 \le k \le 1$	$15 \le x \le 50$	$0 < \eta_{rec,d} <$	$0 < p < 50$

Updated data/information included

- New and updated tables regarding the identity and distribution of ODS substitutes for both developing and developed countries. (Tables 7.3, 7.3a, 7.3b, 7.3c)

TABLE 7.3 (UPDATED)
DISTRIBUTION OF HFC USE BY APPLICATION AREA FOR 2015

COUNTRY	REFRIGERATION AND AIR CONDITIONING	AEROSOLS	FOAM BLOWING AGENTS	FIRE PROTECTION AND OTHERS
Article 5 Parties[a]	88 %	6 %	3 %	3 %
Non-Article 5 Parties[a]	57 %	22 %	19 %	2 %

Source: UNEP-TEAP (2016b)

[a] See list of Article 5 and Non-Article 5 Parties to the Montreal protocol at the Unep Ozone Secreteriat web page

TABLE 7.3C (NEW)
HFC CONSUMPTION FOR REFRIGERATION AND AIR CONDITIONING, PER CENT OF TOTAL BY MANUFACTURING AND SERVICING FOR 2015

	Manufacturing	Servicing
Article 5 Parties[a]	68	32
Non-Article 5 Parties[a]	53	47

Source: UNEP-TEAP (2016b)

[a] See list of Article 5 and Non-Article 5 Parties to the Montreal protocol at the Unep Ozone Secreteriat web page

Thank you

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

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