ECOLE DES MINES DE PARIS
ARMINES
CENTRE D'ENERGETIQUE

REPORT PREPARED WITH SUPPORT FROM

US EPA and ADEME

Determination of comparative HCFC and HFC emission profiles for the Foam and Refrigeration sectors until 2015

Part 1 – Refrigerant emission profiles

April 2004

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1. Method of calculation, data and databases

1.1 Calculation method for emission prevision of refrigerants

The Tier 2 method, as defined in the IPCC guidelines /2/ proposes a calculation for HFC refrigerant emissions from equipment:

- during the manufacturing process,
- during the lifetime, and
- at the end of life of equipment.

This approach of looking at refrigerating equipment from cradle to grave (see figure 1.1) covers all possible emissions but needs to be worked out in order to be consistent.

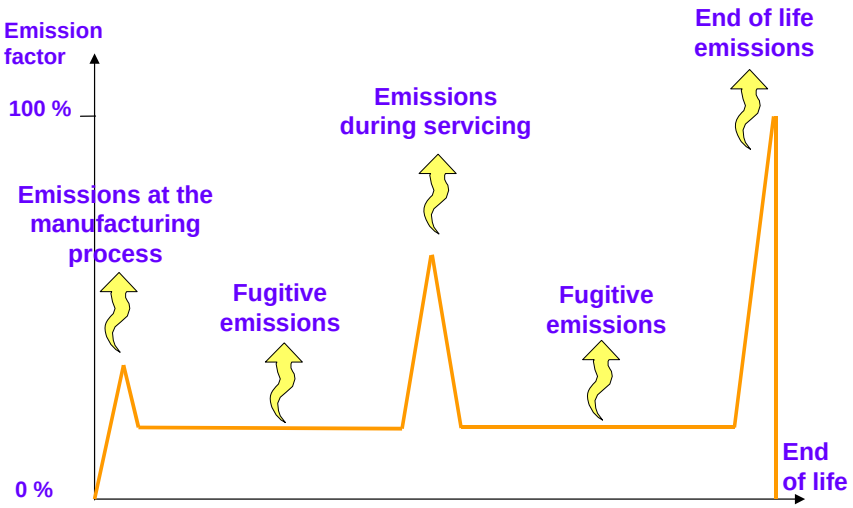


Figure 1.1: Types of emissions from cradle to grave from refrigerating equipment

Annex O to this section details the equations for calculations of the different types of refrigerants banked in all categories of refrigerating equipment, and the quantities emitted. Those equations are consistent with the IPCC Guidelines. This method has been used for nearly seven years to realise refrigerant inventories and emission previsions for the French Government /6/, /7/, /8/, and also to establish global inventories /4/, /5/.

♦ **Emissions at the manufacturing process**

In the case of mass production of equipment, the direct emissions are usually very small. It is possible that, in the case of field assembled systems, the emissions during installation maybe higher but not substantial. The key issue relative to charging and topping up refrigerating equipment is mainly **the emissions due to refrigerant handling.**

Refrigerant handling covers more than the sole manufacturing process of equipment. There needs to be included:

- splitting the bulk refrigerant in large containers into smaller volumes of refrigerant,
- losses related to connecting the smaller refrigerant volumes to equipment, and
- **capacity "heels".**

The capacity "heels" represent the main loss during refrigerant handling. They consist of the vapour inside the container that cannot be extracted due to pressure equilibrium (vapour heel) and the liquid phase remaining in the refrigerant volume(liquid heel). Based on the recovery policy of the main refrigerant distributor in France, it can be derived that those heels represent between **5 and 10 % of the total amount of refrigerant sales,** including the charge of new equipment and the recharge of all the fleets of refrigerating equipment.

A first improvement applied to the Tier 2 method is the inclusion of the emissions from the heels in the total sales of refrigerant; one therefore needs to introduce a complementary equation in the Tier 2 method (see Annex O).

- **Emissions during the lifetime of equipment**

Leaks during the lifetime of equipment depend on the application, e.g., domestic refrigerators have very low emission rate during their lifetime. On the contrary, many commercial centralised equipment and transport refrigerated systems are highly emissive. **Emission previsions need to be based on feedback from the field,** and field data from each country will greatly improve a number of global assumptions made in this study. In large commercial facilities or in industrial processes, the most precise approach to determine emissions is the collection of invoices of refrigerants used for system maintenance and for recharges.

For the purpose of accuracy, mobile air-conditioning systems require more sophisticated methods. One usually forms groups of vehicles of different vintages where the remaining refrigerant in the system is carefully recovered and measured by accurate weighing. By determining the difference between the initial refrigerant charge and the recovered charge, it is possible to establish average levels of refrigerant emissions.

- **Emissions from equipment at end of life**

Emissions from equipment at end of life depend on regulatory policies in different countries, and on the recovery efficiency. For the inventory determination method, it is essential to have the correct lifetime of equipment, and annual market data for a number of past years equal to the lifetime of the equipment. This point is crucial for almost every type of application due to:

- The rapid change of refrigerant types in relation to changing Montreal Protocol regulations, and particularly in relation to more stringent regional or national regulations,
- The rapid market growth of a certain equipment type, e.g. mobile air conditioning systems in recent years in Europe, or rapid annual growth in China,
- The change in the regulations of recycling policies for dealing with equipment at its end of life.

Taking into account

(1) the large number of equipment,
(2) the large variation in equipment types,
(3) the refrigerant charge amounts, and
(4) the different refrigerant types and their GWPs,

a large database has to be built up, on an application by application basis. For each application, **the fleet has to be derived for all the years covering the lifetime of this type of equipment**. Moreover, as the determination of inventories is performed on an annual basis, updating of the database is a necessary factor to take into account.

1.2 Refrigerants and regulations

The use of CFCs, HCFCs or HFCs and other refrigerants is governed by control schedules, which have been continuously adjusted since the Montreal Protocol has been ratified. For developed countries (the non_Article 5(1) countries as defined under the Montreal Protocol), the phase-out of CFCs and HCFCs has been or will be earlier than in the developing countries (the Article 5(1) countries). Moreover, in the non Article 5(1) country group, the European Union has accepted a much tighter control schedule for phasing out CFCs (in the past) and HCFCs.

♦ Non-Article 5(1) Countries

The CFC phase-out schedule as valid for the non-Article 5(1) countries is presented in Figure 1.2. Via the EU regulation 3093/94 CFCs were phased out one year before the phase-out as defined in the Montreal Protocol, i.e. by 31 December 1994.

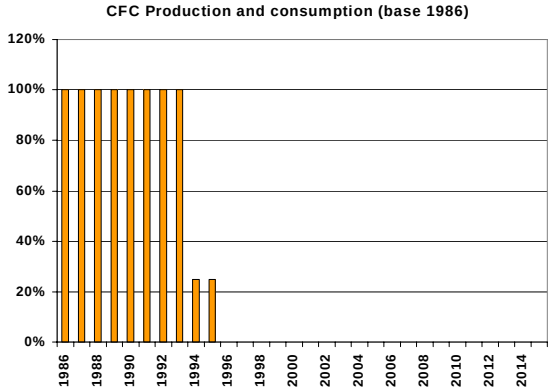


Figure 1.2: CFCs phase out for non-Article 5 countries.

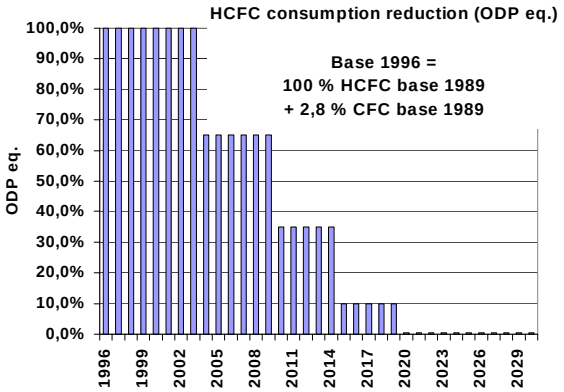


Figure 1.3: HCFCs phase out in non-Article 5 countries (except EU).

As indicated Figure 1.3, the HCFC consumption base levels refer to the 1989 HCFC consumption level plus 2.8% of the 1989 CFC consumption, ODP weighted. On the basis of a certain ODP for HCFC-22 and CFCs (0.055 and 1.0, respectively), the percentage of 2.8 means that if all CFCs would be replaced by HCFC-22, about 55% of the CFC consumption in tonnes would be replaced by HCFC-22.

Figure 1.3 clearly shows that even for non-Article 5(1) countries, brand new equipment charged with HCFC-22 can be manufactured and sold until 31 December 2009. Typically, the U.S. and many developed countries continue to use HCFC-22 for air-conditioning equipment.

As indicated in Figure 1.4, the EU regulation has changed the reference line for HCFC consumption, reducing the additional quantities of ODP weighted CFCs by nearly 30% (from 2.8 to 2.0%). Moreover, the HCFC phase-out date has been brought forward by some 7 years.

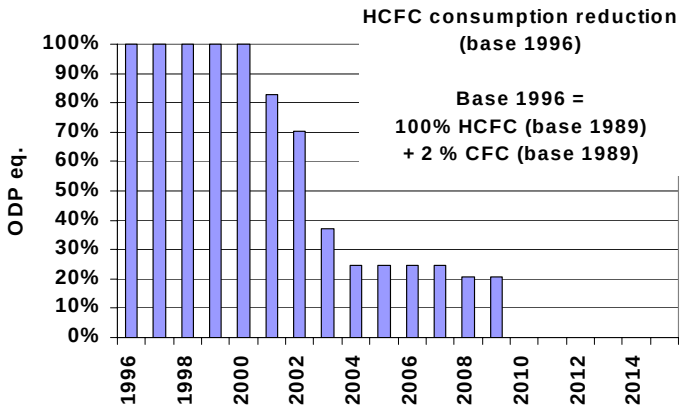


Figure 1.4: European Union - (European regulation 2037/2000).

As indicated in Table 1.1 a number of additional restrictions have been issued via the European regulation 2037/2000. The regulation is equipment type specific, and it can be derived that the effective phase-out date was 1 January 2001 for virtually all new refrigerating equipment; a number of some air-conditioning systems are exempted until 2003/2004.

Equipment	Date of prohibition of HCFC use for the manufacturing of new equipment	Date of prohibition of use of virgin HCFCs for servicing needs	Date of prohibition of use of all sorts of HCFCs for servicing needs
Type 1	January 1st , 1996	January 1st , 2010	January 1st , 2015
Type 2	January 1st , 1998		
Type 3	January 1st , 2000		
Type 4	January 1st , 2001		
Type 5	July 1st , 2002		
Type 6	January 1st , 2004		
Type 7	January 1st , 2009		

Type 1 :	Direct evaporating systems (not confined)
	*Domestic refrigerators and freezers
	*Mobile air-conditioning systems (road transport) except military applications
Type 2 :	Railway air-conditioning systems
Type 3 :	*Cold rooms and refrigerated storage
	*Equipment with driving shaft power > 150 kW
Type 4 :	All other refrigerating and air-conditioning systems, not including:
Type 5 :	Fixed air-conditioning systems, with refrigerating capacity < 100 kW
Type 6 :	Reversible heat pump systems (heating / air conditioning)
Type 7 :	Mobile air-conditioning systems (road transport) for military applications

**Exemption for equipment manufactured that is exported to countries where HCFC use is still allowed.*

Table 1.1 – Restrictions of HCFC use in refrigerating equipment (EU regulation 2037/2000).

- **Article 5(1) Countries**

The CFC consumption and production (see Figure 1.5) for Article 5(1) Countries[1] has a delay of actually 14 years compared to non Article 5(1) countries (1996 compared to 2010). There is an additional possibility of production and consumption of 10% compared to the 1986 level for Basic Domestic Needs of the developing countries, where production can take place in the developed countries.

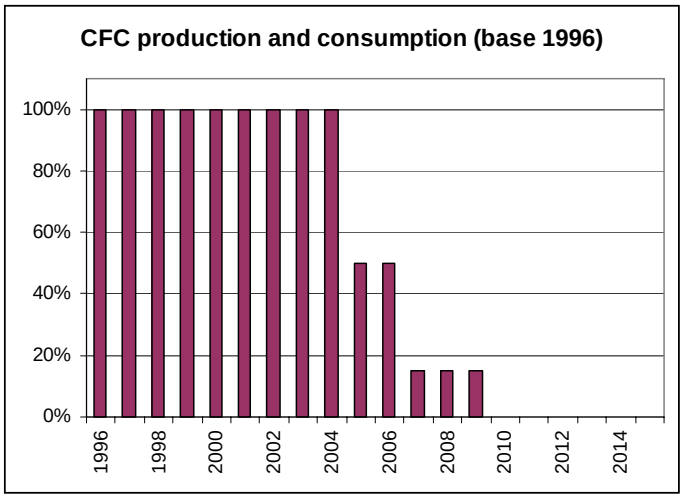


Figure 1.5: CFC phase-out for Article 5(1) Countries.

HCFC production and consumption will be frozen in Article 5(1) countries from 2016 onwards (at the same level as in 2015), with a phase-out in 2040.

All these different constraints based upon global control schedules and more stringent regional and national regulations imply different refrigerant choices in certain countries and country groups. The refrigerant choices need to be taken into account on an application by

[1] Article 5(1) Countries are defined as countries where the CFC consumption is lower than 0.3kg/inhabitant)

application basis. For this project, additional data have been derived from country reports as well as additional data available in publications.

1.3 Consistency and improvement of data quality

Using the Tier 2 method, the consistency in the emission forecast cannot be directly verified. **The first essential cross check can be done by deriving the annual market of the different refrigerant types** based on the initial charge of brand-new equipment (on an application by application basis), and on the recharge at servicing of the different fleets of equipment. By merging those two data series, it should be possible to derive the size of the market for every refrigerant type **and to compare those data to the data submitted by manufacturers and distributors.**

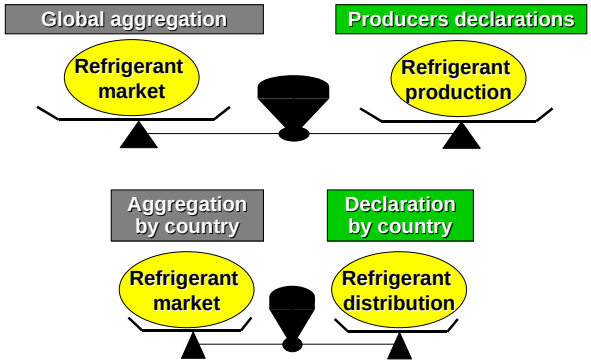


Figure 1.6: Cross check of the annual refrigerant market derived from the initial charges and the recharges with the declarations made by refrigerant producers.

Cross checks can be performed both on a country by country basis and globally (see Figure 1.6).

If the refrigerant inventories and the related emission figures are adequately determined, the difference between the figures submitted and the calculated refrigerant sales will be small. If not, additional analyses are required.

- **Consistency for refrigerating equipment at the global level**

To reach a high accuracy in the sizes of the refrigerant inventories, the first step is to gather reliable data for the equipment numbers. Fortunately, annual statistical data is available for nearly all mass-produced equipment. Some data are published by manufacturer associations, and some (marketing studies) can be purchased from specialised companies. The data on annual equipment sales allow deriving the production and sale figures at the national level for nearly all the OECD countries, and also at the global level, when they are based on production data (see Figure 1.7).

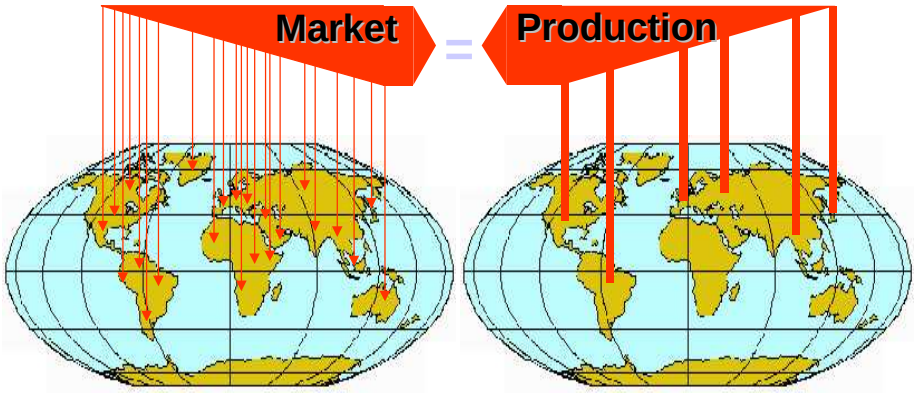


Figure 1.7: Cross check between markets and productions.

At the global level, for a given year one can postulate "Production = Sales" (except for the small stock of equipment produced but not yet sold). For domestic refrigerators, stationary air-conditioning systems, chillers, cars, trucks, buses, reefers… annual numbers of production and sales are available. Application of these numbers avoids double counting, which would easily happen when merging national inventories, particularly if methods of determination are different.

- **Inventories of all refrigerant types and method of aggregation**

The schedule for phasing out CFCs and HCFCs depends for the larger part on country regulations (see section 1.2). Even if only HFC inventory reporting is required under the UN Framework Convention on Climate Change (UNFCCC) /9/, it is required to have information on the forecasts of emissions and on the registration of the change(s) in refrigerant use. Only in this way the sizes of the "banks" of all types of refrigerants --charged in the different types of equipment-- can be determined. The --changing-- trends in the selection of the refrigerant need to include the quantities of HCs and ammonia, which are both being used as HFC replacement options in the European Union.

As shown in Figure 1.8 the bottom-up approach used allows:
- the definition of the annual sales of brand new equipment and the amounts of refrigerant charged in this equipment,
- the determination (dependent on their lifetime)of all the fleets, which yields a cumulative value for the refrigerant bank for the specific application,
- the determination of the refrigerant market for servicing (depending on the leak factor).

Thereafter all the different sectors are aggregated
- refrigerant by refrigerant
- country by country, and
- by country groups and globally.

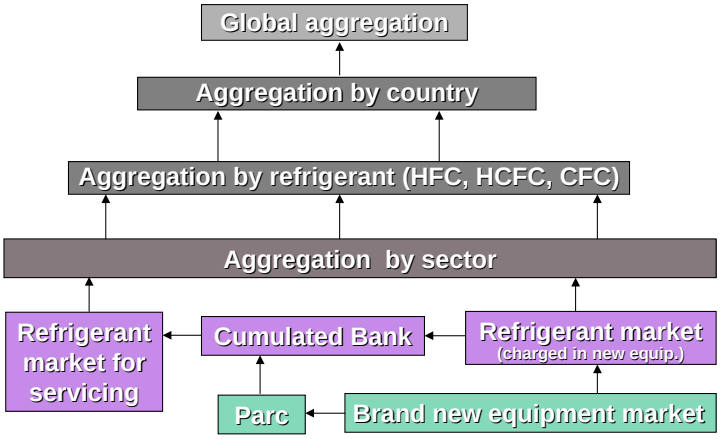


Figure 1.8: Determination of the refrigerant markets.

1.4 Tools for refrigerant inventories and emission previsions

To determine annual emission previsions for all categories of refrigerating equipment, it is necessary to create the tools that permit cumulative improvements in the data quality. The large number of data to be handled makes it necessary:
- to program in a database language,
- to perform calculations based on realistic data,
- to create user friendly interfaces,
- to transfer the results to tables written in spreadsheet language, which tables are based on the prescribed Common Reporting Format (CRF) of the IPCC for HFCs.

For the first year, such a database needs to “create” the fleets of all the different categories and sub-categories of refrigerating equipment. For the years thereafter the updating process requires less efforts and consists of the following input data:

- the annual equipment market for each category in the reference year,
- the type of refrigerant used in brand-new equipment, and possibly also information on the conversion from CFCs or HCFCs to HFCs or other refrigerants,
- the emission factors.

All those elements allow performing:

- calculations of emissions from all existing fleets of equipment,
- calculations of emissions from all types of decommissioned equipment,
- calculation of the amount of recovered or reclaimed refrigerants,
- calculation of the refrigerant banks per category of equipment,
- calculation of the annual refrigerant market sales, per refrigerant type.

As soon as better data become available, the database can be updated in a transparent manner. National, regional or global data reviews are necessary in order to control the quality of the inventory determinations.

A database enables the development of data acquisition in a single way: **improvement**, because it creates storage of data on the refrigerants in use inside the fleets of equipment that have been determined.

1.4.1 Refrigeration equipment and refrigerant bank database

The RIEP software (Refrigerant Inventories and Emission Previsions) is connected to another database, the CDB (Country Data Base), which has been developed to act as a source for economic, demographic, and technical data for countries and groups of countries (see annex P).

RIEP is written in the ACCESS language, and deals with the separate countries, for any given year. Based on inputs from the user interface, RIEP can calculate the emissions during the equipment lifetime (see Figure 1.9). For these calculations, data have to be used for each year of the lifetime of a given equipment type or category.

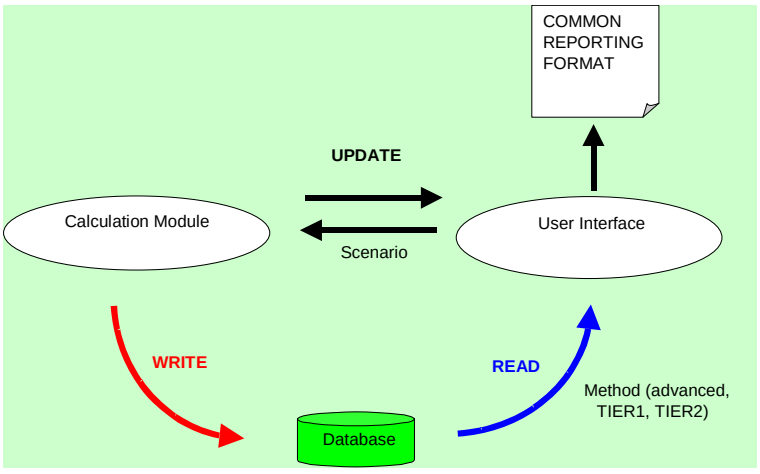


Figure 1.9: Scheme of the application of the RIEP program.

1.4.2 Country Data Base

As indicated in Figure 1.10, if one selects a certain year and either the national or the regional level, the CDB can produce data on:

- demography,
- energy production and consumption,
- agriculture, and
- economy including commerce.

The Country Data Base (CDB), which has been constructed for the determination of global inventories covers 62 countries and 8 regions comprising the remaining 110 countries (see annex P).

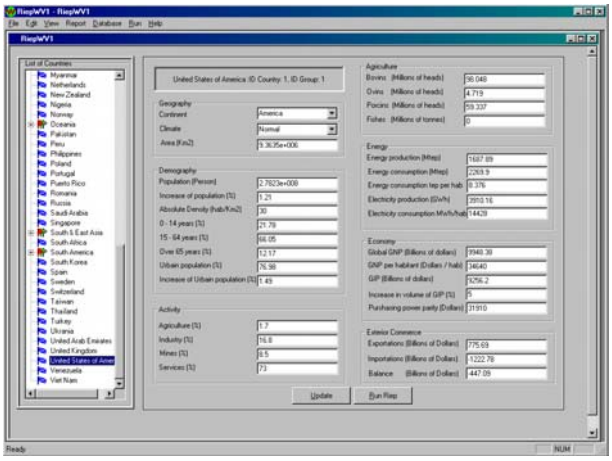


Figure 1.10: Example of a screen of the USA CDB.

For countries where only few specific equipment data is available, some of the general data mentioned above can be used to create ratios between refrigerating equipment, national economy and population. From the CDB, it is possible to run the RIEP program. The CDB is also written in Access and interfaces are handled in the C^{++} language.

2. Inventories for year 2002

Note: In all figures presenting either refrigerant or country shares, the void part corresponds to other refrigerants or country groups, for which the shares are marginal, i.e. lower than 5%.

2.1 Refrigerant market

One of the essential steps in the calculation procedure is the determination of the markets of all different refrigerants by merging the annual refrigerant charges of all types of equipment and the complementary refrigerant charges needed for all servicing operations. When calculating these data, they are cross-checked with refrigerant market data as declared by refrigerant manufacturers and distributors. In many countries the refrigerant quantities sold are monitored, and the refrigerant distributors publish their annual sales of CFC, HCFC, and sometimes HFC refrigerants.

2.1.1 Refrigerant market by type

Table 2.1: Refrigerant market in 2002.

Refrigerant market in 2002		tonnes		ODP tonnes	
CFCs	R-11	5 884	149 260	5 884	118 528
	R-12	131 652		107 954	
	R-115	11 724		4 689	
HCFCs	R-22	345 815	356 790	13 833	14 039
	R-123	7 695		108	
	R-124	3 280		98	
HFCs	R-125	23 473	189 614	-	-
	R-134a	133 322		-	
	R-143a	28 499		-	
	R-152a	1 254		-	
	R-32	3 065		-	
Others	R-717	22 371	23 075	-	-
	R-744	-		-	
	R-600a	703		-	

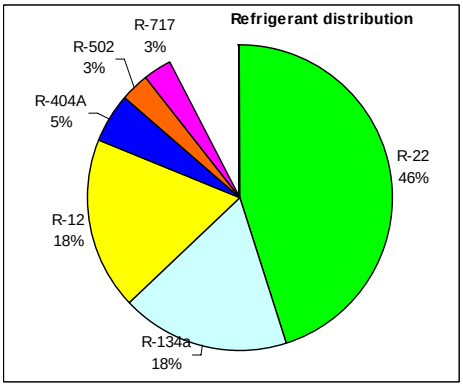


Figure 2.1: Refrigerant share in 2002.

HCFC-22 is the most widely used refrigerant representing nearly half of the global demand. The HFC demand is close to 200,000 metric tonnes in 2002 and the CFC market is still at a level of 150,000 tonnes.

2.1.2 Refrigerant market by sector

Table 2.2: Refrigerant market by sector in 2002.

Market (tonnes)	Domestic	Commercial	Transport	Industry	Stationary AC	Mobile AC
CFCs	6 703	68 166	683	6 706	11 193	55 808
HCFCs	-	161 040	915	26 503	165 499	2 833
HFCs	7 972	48 183	3 936	5 996	26 858	96 670
Others	703	-	-	22 083	289	-
TOTAL	15 378	277 389	5 535	61 287	203 839	155 311
ODP tonnes	*5 673*	*56 666*	*590*	*5 478*	*16 867*	*52 971*

Commercial refrigeration is the most important sector for refrigerant demand. Similar amounts of HCFCs are applied in stationary AC and in commercial refrigeration.

HFCs are mainly used in the Mobile Air Conditioning sector, representing half of the global HFC demand.

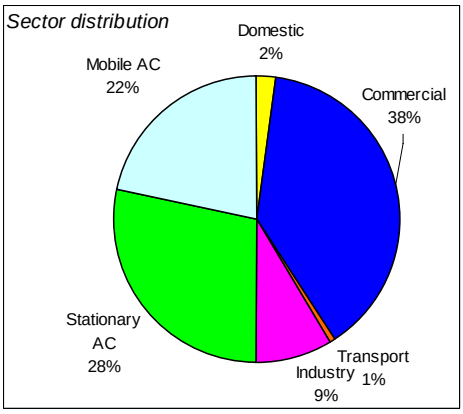


Figure 2.2: Sector share in 2002.

2.1.3 Refrigerant market by country group

Table 2.3: Refrigerant market by region in 2002.

Market (tonnes)	Africa	C&S America	S&E Asia	N&W Asia	China
CFCs	5 524	15 044	21 834	8 288	52 855
HCFCs	5 223	22 294	29 466	14 264	124 794
HFCs	868	3 093	6 255	3 203	3 793
Others	569	2 284	1 007	956	2 029
Total	12 184	42 715	58 561	26 712	183 471

Market (tonnes)	EU	East Europe	Japan	Oceania	USA
CFCs	2 681	1 807	2 415	537	38 274
HCFCs	15 221	7 340	21 319	3 248	113 621
HFCs	47 660	8 666	20 659	2 932	92 485
Others	5 593	3 270	903	704	5 760
Total	71 156	21 083	45 297	7 420	250 140

When only considering the HFC refrigerants, it can be stated that 85% of the refrigerant market can be found in the USA, the EU and Japan. The USA represents nearly half of the global demand, mainly because of the broad use of mobile air conditioning in this country.

If all types of refrigerants are taken into consideration (HFCs, HCFCs, CFCs and others) China has become the second largest market in 2002.

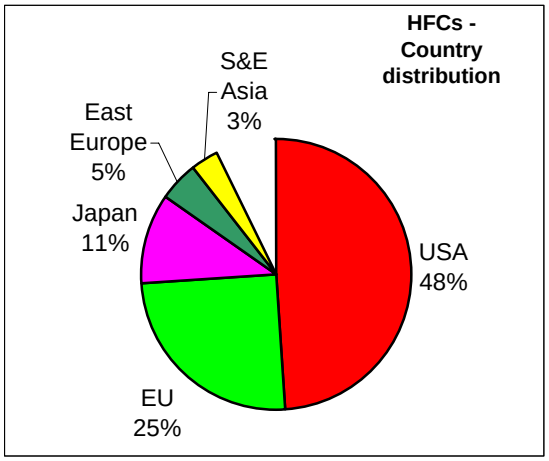


Figure 2.3: HFC demand – Country share.

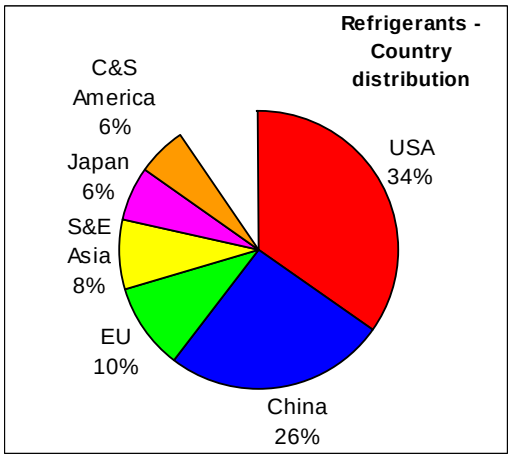


Figure 2.4: All refrigerants demand – Country share.

2.1.4 Refrigerant market: cross-checking with AFEAS data

The annual production of refrigerants has been published by AFEAS since 1990 /1/, in the form of a database with 1930 (for CFCs) as the first year. Via RIEP the annual market of refrigerants can be calculated including the refrigerant charged into new equipment, and the refrigerant sold for servicing. In principle, via RIEP the annual refrigerant needs are calculated.

AFEAS only publishes data when there are more than three “significant” producers. Therefore data are not available for some components of the new HFC blends such as HFC-125 and HFC-32. The fact that these data are missing implies that one cannot verify the penetration rate of the HCFC-22 replacement refrigerants such as R-410A and R-407C.

HCFC-22 sales (tonnes)

Year	AFEAS	RIEP	Deviation
1990	205 097	146 872	-28%
1991	228 164	161 722	-29%
1992	222 610	179 493	-19%
1993	225 019	179 013	-20%
1994	236 159	203 568	-14%
1995	220 089	218 681	-1%
1996	247 012	235 130	-5%
1997	252 261	247 464	-2%
1998	286 336	264 492	-8%
1999	296 140	280 598	-5%
2000	290 984	308 072	6%
2001	308 181	322 290	5%
Cumulative total	**3 018 052**	**2 747 395**	**-9%**

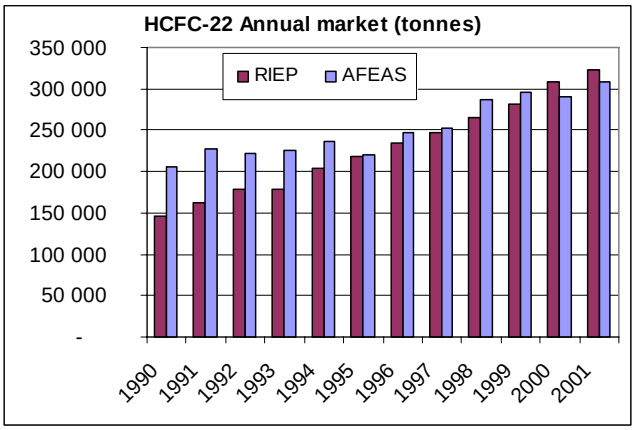


Table 2.4: HCFC-22 production and demand cross checking.

Globally, taking into account the cumulative sales from 1990 to 2001, when comparing AFEAS data plus declarations of sales of China, India, Korea, and Russia, RIEP underestimates the sales of about 9%. The main differences are found from 1990 to 1994 where systematically RIEP underestimates the sales between 16 to 40%. From 1995 to 2001 the differences are very small. Additional work is needed to understand those differences.

HFC-134a sales (tonnes)

Year	AFEAS	RIEP	Deviation
1990	-	202	
1991	2 127	398	-81%
1992	5 961	1 826	-69%
1993	24 501	12 026	-51%
1994	46 065	26 777	-42%
1995	61 230	39 405	-36%
1996	70 973	46 828	-34%
1997	90 839	54 047	-41%
1998	96 514	59 722	-38%
1999	111 110	74 021	-33%
2000	110 597	88 620	-20%
2001	109 803	119 618	9%
Cumulative total	**729 720**	**523 490**	**-28%**

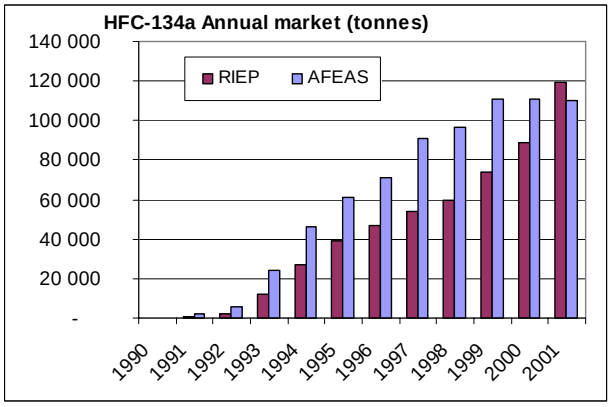


Table 2.5: HFC-134a production and demand cross checking.

From 1990 to 2001, the AFEAS figures show a much more rapid growth of the HFC-134a production than shown by RIEP calculations of refrigerant demand. The difference decreases in 2001 with the production stabilising at the level of 110,000 tonnes per year, while the demand continuously increases (120,000 tonnes in 2001) following RIEP calculations.

Comparison of the total markets of HCFC-22 and HFC-134a

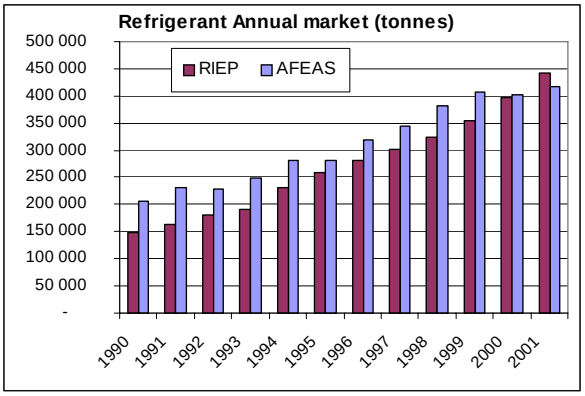
It should be stated that the RIEP model determines the annual needs of refrigerants based on the needs for charging brand new equipment and the needs for servicing all refrigerating systems in use. So differences may be possible, for example when consumers are stockpiling.

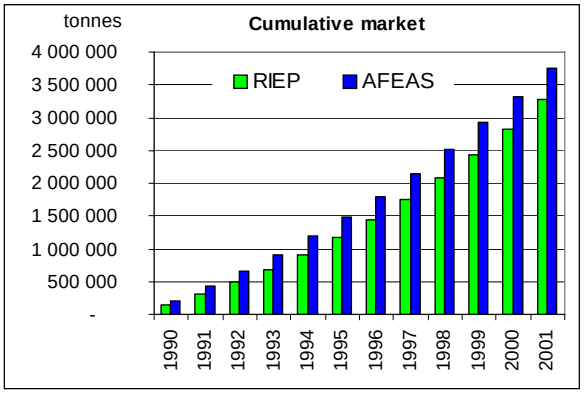
When comparing the cumulative markets from 1990 to 2001 for both HCFC-22 and HFC-134a as published by AFEAS and as calculated by RIEP, differences are small. RIEP underestimates the cumulative market by less than 13%. Table 2.6 indicates also that the deviation is significantly decreasing for years 2000 and 2001, and this trend should be confirmed in the next coming years.

Table 2.6: Comparison of the total markets of HCFC-22 and HFC-134a.

HCFC-22 & HFC-134a sales (tonnes)

Year	AFEAS	RIEP	Deviation
1990	205 097	147 074	-28%
1991	230 291	162 120	-30%
1992	228 571	181 319	-21%
1993	249 520	191 040	-23%
1994	282 224	230 344	-18%
1995	281 319	258 086	-8%
1996	317 985	281 958	-11%
1997	343 100	301 511	-12%
1998	382 850	324 214	-15%
1999	407 250	354 619	-13%
2000	401 581	396 692	-1%
2001	417 984	441 908	6%
Cumul.	3 747 772	3 270 886	-12,7%





2.2 Refrigerant bank

2.2.1 Refrigerant bank by type

Table 2.7: Refrigerant bank in 2002

Refrigerant bank in 2002		tonnes		ODP tonnes	
CFCs	R-11	45 444	592 976	45 444	458 065
	R-12	486 533		398 957	
	R-502	60 999		13 664	
HCFCs	R-22	1 397 057	1 500 161	55 882	57 942
	R-408A	32 727		622	
	R-401A	26 630		826	
	R-123	43 746		612	
HFCs	R-134a	380 249	488 515	-	-
	R-404A	78 712		-	
	R-407C	12 003		-	
	R-410A	7 151		-	
	R-507	10 402		-	
Others	R-717	106 560	109 317	-	-
	R-744	-		-	
	R-600a	2 757			

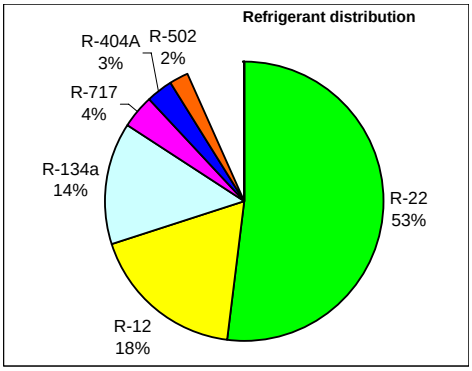


Figure 2.6: Refrigerant share in 2002.

In 2002, the global bank amounts to about 2,700,000 metric tonnes split in 1.5 million tonnes of HCFCs, nearly 490,000 tonnes of HFCs, 590,000 tonnes of CFCs and 110,000 tonnes of non-fluorinated refrigerants.

2.2.2 Refrigerant bank by sector

Table 2.8: Refrigerant bank by sector in 2002.

Bank (tonnes)	Domestic	Commercial	Transport	Industry	Stationary AC	Mobile AC
CFCs	107 039	200 907	3 274	48 572	83 891	149 293
HCFCs	-	321 434	3 157	127 517	1 027 572	20 481
HFCs	49 873	83 470	9 513	16 226	80 906	248 528
Others	2 757	-	-	105 306	1 254	-
TOTAL	159 669	605 811	15 944	297 621	1 193 624	418 301
ODP tonnes	*89 501*	*154 624*	*1 785*	*28 125*	*118 727*	*137 598*

Nearly half of the refrigerant bank can be found in stationary air conditioning (see Figure 2.7). Because of the lower emission rates, this sector is ranked second rank in terms of the refrigerant demand, where commercial refrigeration is the most important (see Figure 2.2).

The largest bank of CFCs can be found in commercial refrigeration equipment.

The HCFC bank is specifically contained in the stationary AC sector.

The largest part of the HFC bank is contained in mobile AC equipment.

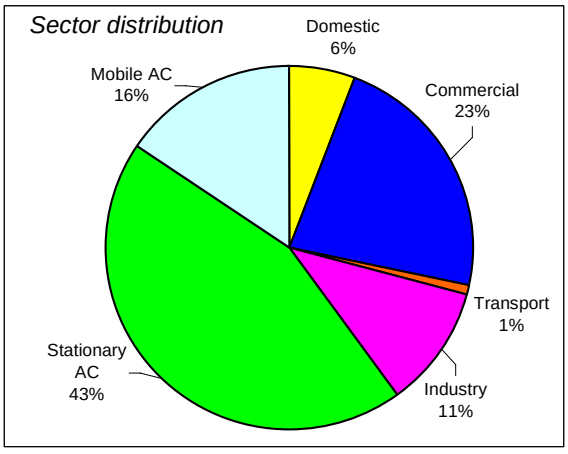


Figure 2.7: Sector share in 2002.

2.2.3 Refrigerant bank by country group

Table 2.9: Refrigerant bank by region in 2002.

Bank (tonnes)	Africa	C&S America	S&E Asia	N&W Asia	China
CFCs	23 360	59 777	85 415	35 573	163 540
HCFCs	19 406	62 331	131 413	57 362	273 242
HFCs	1 900	7 291	17 276	7 838	10 269
Others	2 681	10 722	4 970	4 388	9 353
Total	47 348	140 122	239 073	105 161	456 404

Bank (tonnes)	EU	East Europe	Japan	Oceania	USA
CFCs	32 298	20 229	20 833	3 792	148 160
HCFCs	101 717	33 008	147 424	15 535	658 723
HFCs	113 233	24 631	60 976	7 537	237 563
Others	27 353	15 285	4 411	3 268	26 885
Total	274 601	93 154	233 644	30 132	1 071 331

The share of the refrigerant bank for each region or country is identical to the share of the refrigerant market for each region or country (see Figures 2.8 and 2.9). In the USA nearly half of the HFC bank can be found, as well as 40 % of the global bank of all refrigerants. Because of its rapid economic growth, China has become the country listed second in terms of refrigerant banks, and has the largest CFC bank.

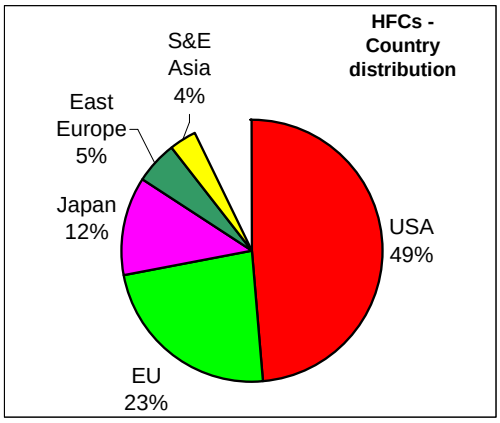


Figure 2.8: HFC bank – Country share.

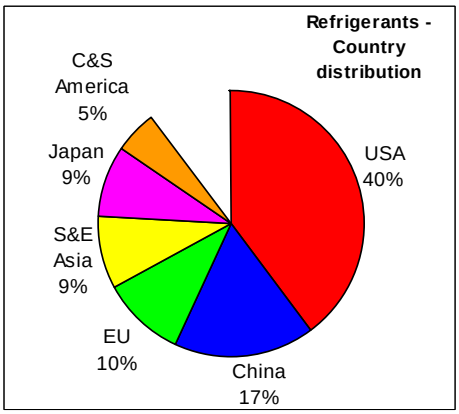


Figure 2.9: Bank of all refrigerants – Country share.

2.3 Refrigerant emissions

2.3.1 Refrigerant emissions by type

Table 2.10: Refrigerant emissions in 2002.

Refrigerant emissions in 2002		tonnes	
CFCs	R-11	7 106	144 225
	R-12	126 644	
	R-115	10 475	
HCFCs	R-22	229 303	236 318
	R-123	4 151	
	R-124	2 864	
HFCs	R-125	9 872	100 644
	R-134a	74 343	
	R-143a	14 765	
	R-152a	1 095	
	R-32	568	
Others	R-717	17 913	17 948
	R-744	-	
	R-600a	35	

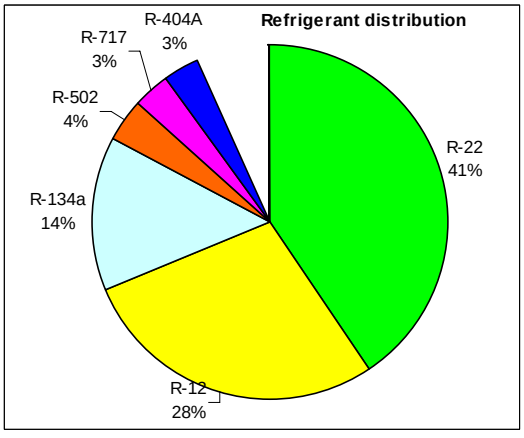


Figure 2.10: Refrigerant share in 2002.

The refrigerant emissions in 2002 are close to 500,000 metric tonnes including all emissions types.

2.3.2 Refrigerant emissions by sector

Table 2.11: Refrigerant emissions by sector in 2002.

Emissions (tonnes)	Domestic	Commercial	Transport	Industry	Stationary AC	Mobile AC
CFCs	8 434	54 865	1 183	6 859	13 069	59 815
HCFCs	-	107 119	1 553	23 533	95 932	8 181
HFCs	481	22 979	3 265	1 884	6 064	65 970
Others	35	-	-	17 704	209	-
TOTAL	8 950	184 963	6 002	49 981	115 274	133 965

Fugitive emission rates in the commercial refrigeration sector are higher than in other sectors.

Commercial refrigeration is the sector with the largest refrigerant emissions.

If only HFC refrigerants, the mobile AC is the main contributor.

Stationary AC equipment is characterised by lower emission rates, and in this sector a quarter of the global emissions in 2002 occurs.

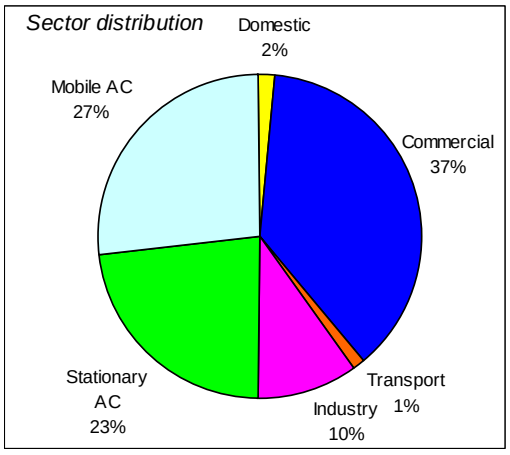


Figure 2.11: Sector share in 2002.

2.3.3 Refrigerant emissions by country groups

Table 2.12: Refrigerant emissions by region in 2002.

Emissions (tonnes)	Africa	C&S America	S&E Asia	N&W Asia	China
CFCs	4 312	12 331	16 809	6 762	37 480
HCFCs	3 641	16 304	24 373	10 064	70 093
HFCs	405	1 420	2 232	1 453	588
Others	478	1 744	894	807	1 583
Total	8 837	31 798	44 307	19 085	109 744

Emissions (tonnes)	EU	East Europe	Japan	Oceania	USA
CFCs	6 837	2 981	4 767	771	51 176
HCFCs	16 001	6 966	18 029	2 413	68 435
HFCs	19 565	4 019	12 283	1 779	56 902
Others	3 915	2 631	691	559	4 645
Total	46 318	16 598	35 770	5 520	181 158

Nearly 60% of the HFC emissions can be attributed to the U.S.A. The use of disposable cans containing HFC-134a for automotive uses forms an additional source of refrigerant emissions during servicing.

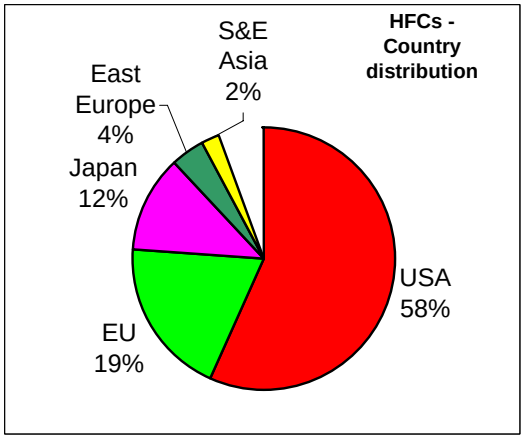


Figure 2.12: HFC emissions – Country share.

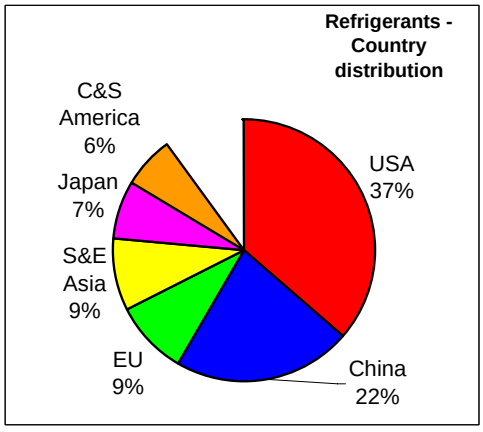


Figure 2.13: Refrigerant emissions – Country share.

2.4 Equivalent CO_2 emissions

2.4.1 Refrigerant emissions by type

Table 2.13: Refrigerant emissions in 2002 expressed as CO_2 equivalent.

		x1000 tonnes	
CO2 emissions in 2002		2nd ass.	
CFCs	R-11	27 005	1 150 237
	R-12	1 025 816	
	R-115	97 417	
HCFCs	R-22	343 955	345 675
	R-123	373,6	
	R-124	1 346	
HFCs	R-125	27 643	180 920
	R-134a	96 646	
	R-143a	56 108	
	R-152a	153	
	R-32	369	

The GWP values are taken from the Second Assessment Report /3/ (see Annex N).

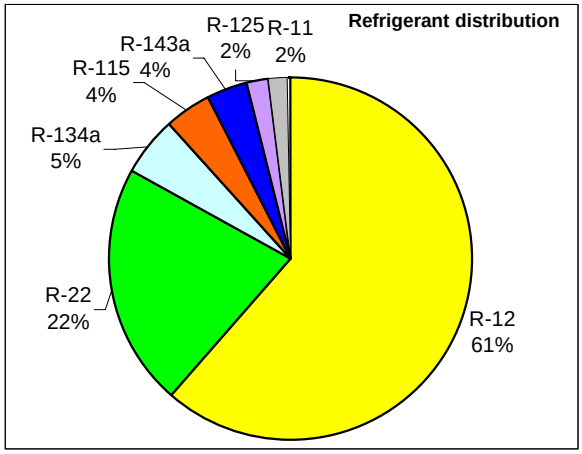


Figure 2.14: Refrigerant shares in 2002.

In 2002, CFC-12 still represents 61% of the total contribution of all refrigerants to global warming. However, the CFC-12 emissions are only 25% of the total emissions in mass.

HCFC-22 accounts for 45% of the total refrigerant emissions in mass, however, in 2002, it only contributes 22% to the refrigerant emissions expressed in CO_2 equivalents.

HFC-134a represents 15% of the refrigerant emissions in mass, whereas its emissions are 5% of the total expressed in CO_2 equivalents.

2.4.2 Refrigerant emissions by sector

Table 2.14: Refrigerant CO_2 emissions by sector in 2002 (2^{nd} assessment Report IPCC).

CO2 emis. (ktonnes)	Domestic	Commercial	Transport	Industry	Stationary AC	Mobile AC
CFC	68 315	452 870	10 318	57 915	76 319	484 502
HCFC	-	157 729	2 330	35 300	138 045	12 271
HFC	625	72 749	8 379	5 006	8 390	85 770
Other	1	-	-	-	-	-
TOTAL	68 941	683 347	21 027	98 220	222 754	582 543

In 2002, CFCs are still used in commercial refrigeration and in mobile AC in the Article 5(1) countries. The higher GWP of CFC-12 (8 times that of HFC-134a) emphasises the importance of these sectors.

If only HFC refrigerant emissions are considered, the commercial refrigeration and the MAC sector contribute to the same degree in CO_2 equivalents Nevertheless, the emissions from the MAC sector are three times larger in terms of refrigerant quantity.

Low temperature refrigerants such as R-404A and R-507 have a GWP of about 3800. The GWP of HFC-134a is 1300.

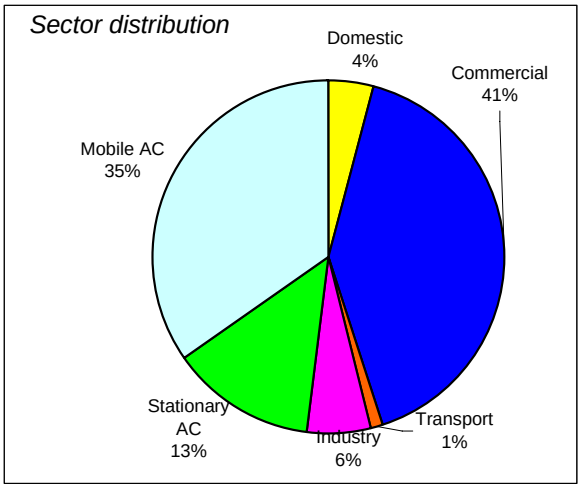


Figure 2.15: Sector shares in 2002.

2.4.3 Refrigerant emissions by country groups

Table 2.15: Refrigerant CO_2 emissions by region in 2002.

CO_2 emis.(ktonnes)	Africa	C&S America	S&E Asia	N&W Asia	China
CFC	34 798	101 482	135 382	54 293	302 886
HCFC	5 462	24 457	36 532	15 083	104 865
HFC	533	1 870	3 827	2 239	798
Other	-	-	-	-	0
Total	40 793	127 809	175 741	71 615	408 549

CO_2 emis.(ktonnes)	EU	East Europe	Japan	Oceania	USA
CFC	55 381	24 023	36 864	6 275	398 853
HCFC	23 632	10 220	26 712	3 567	95 145
HFC	39 525	10 260	20 317	3 114	98 438
Other	1	0	-	-	-
Total	118 538	44 502	83 893	12 955	592 436

In Europe the role of the high GWP HFC refrigerants (R-404A, R-507) is more important than in other developed countries where HFC-134a (MAC sector) is more widely used. Because of this share, the EU contribution to global CO_2 equivalent emissions increases to 22% (compared to 19% of the HFC emissions mass-wise).

The Article 5(1) countries in Asia and South America, where CFC-12 is still used, represent half of world wide refrigerant emissions in CO_2 equivalents. The share of the U.S.A. in the total emission of all refrigerants still amounts to 36%.

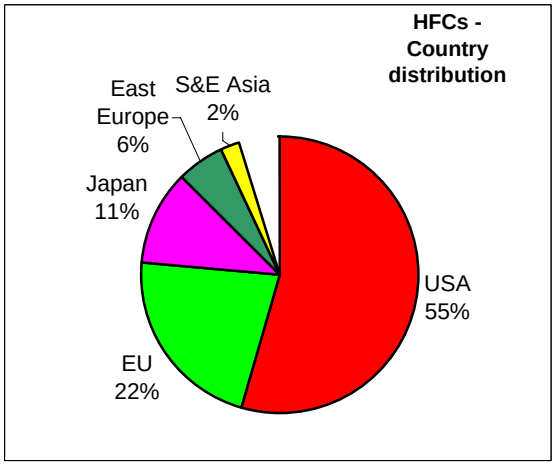


Figure 2.16 : HFC CO_2 emissions – Country shares.

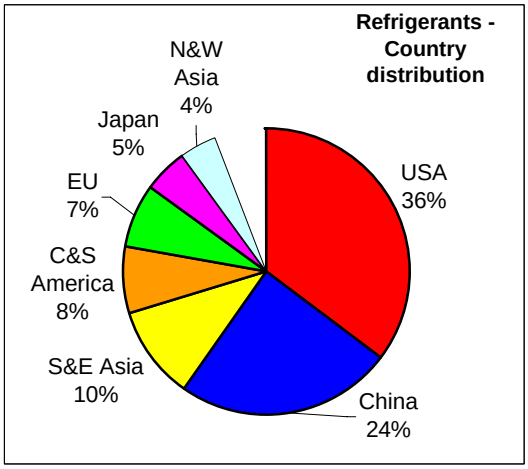


Figure 2.17: All refrigerants CO_2 emissions – Country shares.

2.5 Refrigerant recovery

2.5.1 Refrigerant recovery by type

Table 2.16: Refrigerant recovery in 2002.

Refrigerant recovery in 2002		tonnes	
CFCs	R-11	596	6 502
	R-12	4 070	
	R-502	1 835	
HCFCs	R-22	19 517	23 295
	R-408A	1 909	
	R-401A	1 870	
	R-123	-	
HFCs	R-134a	594	1 628
	R-404A	1 034	
	R-407C	-	
	R-410A	-	
	R-507	-	
Others	R-717	1 048	1 048
	R-744	-	
	R-600a	-	

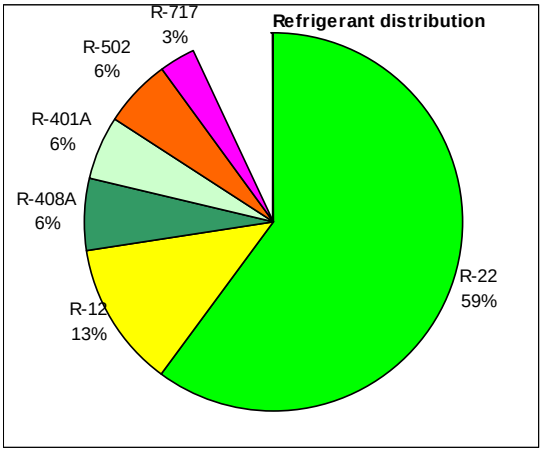


Figure 2.18: Refrigerant share in 2002.

In 2002, refrigerant recovery is estimated at 32,500 metric tonnes in 2002, mainly consisting of HCFC-22 and CFCs.

The total quantities of recovered refrigerants are determined using assumptions on an application by application basis and for country groups. Very few data are available on the quantity that is effectively recovered. Moreover, and particularly in the case of CFC-12, recovered refrigerant can be directly reused in other equipment without bringing it to refrigerant reclaim equipment. A high level of uncertainty can be concluded here. If the circumstances in practice are different from the assumptions made for the calculations, a part of the quantity assumed to be recovered in the calculations might well be emitted.

Of the annual refrigerant market in 2002, the recovered refrigerants only represent 5%.

2.5.2 Refrigerant recovery by sector

Table 2.17: Refrigerant recovery by sector in 2002.

Recovery (tonnes	Domestic	Commercial	Transport	Industry	Stationary AC	Mobile AC
CFCs	242	3 692	407	1 178	983	-
HCFCs	-	9 167	547	1 294	12 288	-
HFCs	-	541	1 069	-	18	-
Others	-	-	-	1 028	20	-
TOTAL	242	13 400	2 023	3 500	13 308	-

Recovery is not applied in the automotive sector and in domestic refrigeration, except in some European countries.

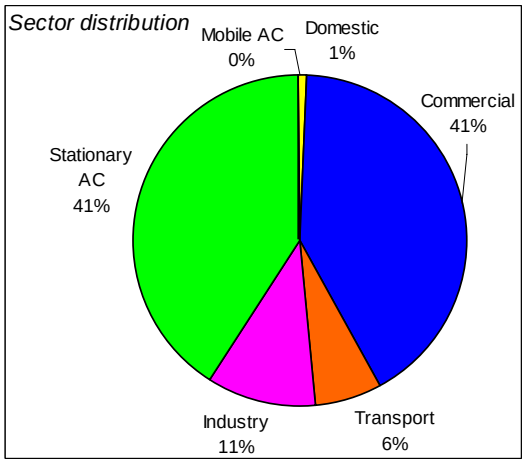


Figure 2.19: Sector share in 2002.

2.5.3 Refrigerant recovery by country group

Table 2.18: Refrigerant recovery by region in 2002 (in tonnes).

Recovery (t)	Africa	C&S America	S&E Asia	N&W Asia	China
CFCs	739	1 668	3 581	1 050	901
HCFCs	271	670	4 486	561	427
HFCs	187	732	438	615	83
Others	9	59	49	21	69
Total	1 205	3 130	8 555	2 246	1 480

Recovery (t)	EU	East Europe	Japan	Oceania	USA
CFCs	3 585	301	1 762	201	5 698
HCFCs	2 494	841	4 246	312	16 154
HFCs	7 284	581	5 808	681	22 500
Others	295	102	50	37	357
Total	13 657	1 826	11 866	1 231	44 709

There is no effective recovery of refrigerants in Article 5(1) countries. The regional distribution is virtually the same as the global refrigerant banks distribution.

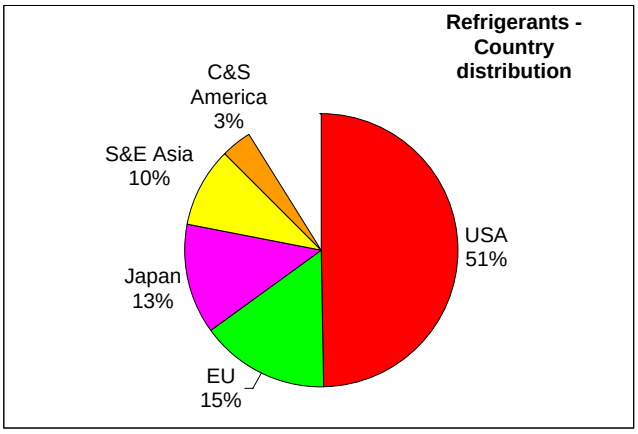


Figure 2.20 : Refrigerants recovery – Country share.

3. Forecasting 2002-2015

3.1 Scenarios for projections to 2015

Projections are made using 3 scenarios, which take into account regulation schedules, technological choices, and professional practices.
Each of the following sectors is studied independently:
- domestic refrigeration
- commercial refrigeration
- refrigerated transport
- industrial refrigeration
- stationary air conditioning
- mobile air conditioning.

Calculations are made for ten countries or country groups
- Africa
- America (South and Central)
- Asia (North and West)
- Asia (South and East)
- China
- Europe (Eastern and Russia)
- European Union
- Japan
- Oceania
- The United States of America.

All refrigerants are traced in order to obtain a better consistency. The use of CFCs, HCFCs or HFCs and other refrigerants is related to regulations since the Montreal Protocol has entered into force. For developed countries (the non-Article 5(1) countries in the Montreal Protocol), the phase-out of CFCs and HCFCs is or will be implemented at an earlier stage than for developing countries (the Article 5(1) countries). Moreover, in the non-Article 5(1) countries group, Europe decided a tighter schedule for phasing out CFCs and HCFCs.

The market growth is estimated using the growth in the last ten-years , taking into account the economical situation in each country group.

Scenario 1: Business As Usual
The usual practices and emission rates are kept unchanged for the next 12 years. Recovery efficiency is assumed to not increase. Nevertheless, regulations related to refrigerant phase-out are considered in the case of refrigerant replacements.

Scenario 2: Emission Reduction 1st Tier
Improvements are made in different sectors thereby reducing the refrigerant emissions in CO_2 equivalents:
- The system leak tightness is improved by choosing more reliable components.
- The recovery efficiency is improved at servicing and at the end of life. Recovery is applied in sectors where it was not done before.
- Technologies for the reduction of the refrigerant charge are introduced (compactness, indirect systems).
- Lower GWP refrigerants are preferred whenever possible.

Scenario 3: Partial phase-out of HFCs
More efforts are done related to leak tightness, recovery efficiency, charge reduction and low GWP refrigerant selection, also mentioned for scenario 2.

Fugitive emissions are reduced via better servicing and the use of control devices on refrigeration equipment. Refrigerant recovery is generally applied in all sectors; operators are assumed to be well qualified and equipped with adapted tools. Technological choices are based on selecting lowest possible refrigerant charges and low GWP refrigerants whenever possible.

All assumptions are detailed on a country by country and sector by sector basis in annexes A to J.

3.2 Results of projections to 2015: refrigerant market

3.2.1 Refrigerant market by type

Tables 3.1: Refrigerant markets in 2015.

Tonnes	CFCs	HCFCs	HFCs	HCs	Total
SC.1	11 579	485 079	590 561	1 338	1 088 557
SC.2	9 892	396 958	498 800	5 891	911 541
SC.3	8 101	324 878	439 881	9 071	781 929
ODP tonnes	CFCs	HCFCs	HFCs	HCs	Total
SC.1	9 059	19 333	-	-	28 393
SC.2	7 678	15 838	-	-	23 516
SC.3	6 291	12 972	-	-	19 263

In the business as usual scenario, the total refrigerant market, which consists of the refrigerants charged in brand new equipment and the refrigerants needed for servicing, increases from 600,000 tonnes in 2002 to 1.1 million tonnes in 2015 (scenario 1). Detailed data for each refrigerant is presented in annex K. Emission reduction policies result in the reduction of the refrigerant demand for servicing, and this yields a forecast for the refrigerant market to be about 800,000 tonnes in 2015.
The CFC market decreases continuously.

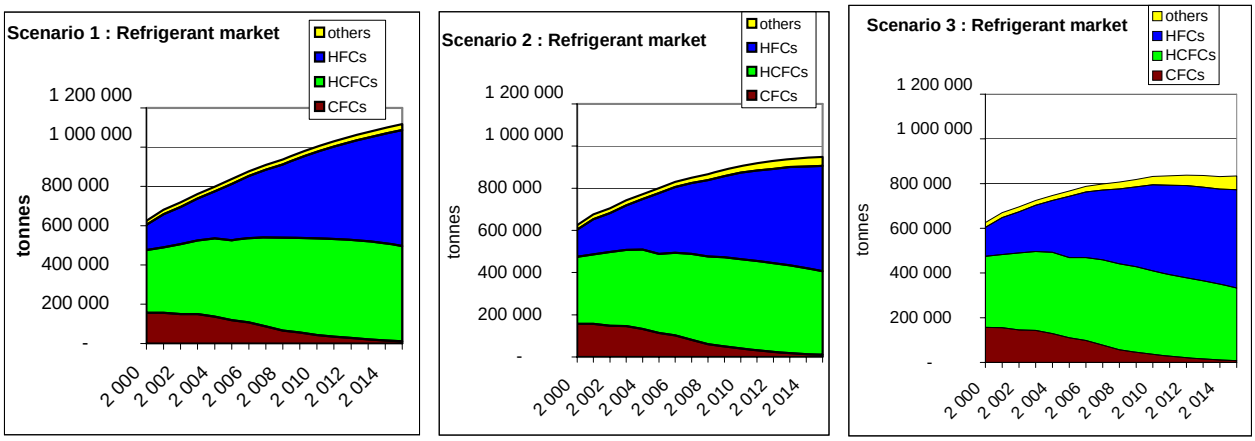


Figure 3.1: Evolution of refrigerant markets.

3.2.2 Refrigerant markets by sector

Table 3.2: Refrigerant markets in 2015 - Sector distribution.

Market (tonnes)	Domestic	Commercial	Transport	Industry	Stationary AC	Mobile AC
SC.1	23 777	501 725	7 806	72 194	318 187	193 904
SC.2	20 007 *-16%*	417 472 *-17%*	6 596 *-16%*	63 894 *-11%*	269 414 *-15%*	171 580 *-12%*
SC.3	17 080 *-28%*	363 822 *-27%*	5 755 *-26%*	50 309 *-30%*	225 764 *-29%*	171 649 *-11%*

ODP tonnes	Domestic	Commercial	Transport	Industry	Stationary AC	Mobile AC
SC.1	574	15 078	47	3 237	7 248	2 249
SC.2	561	12 366	39	2 929	5 439	2 182
SC.3	546	10 716	34	2 228	3 807	1 932

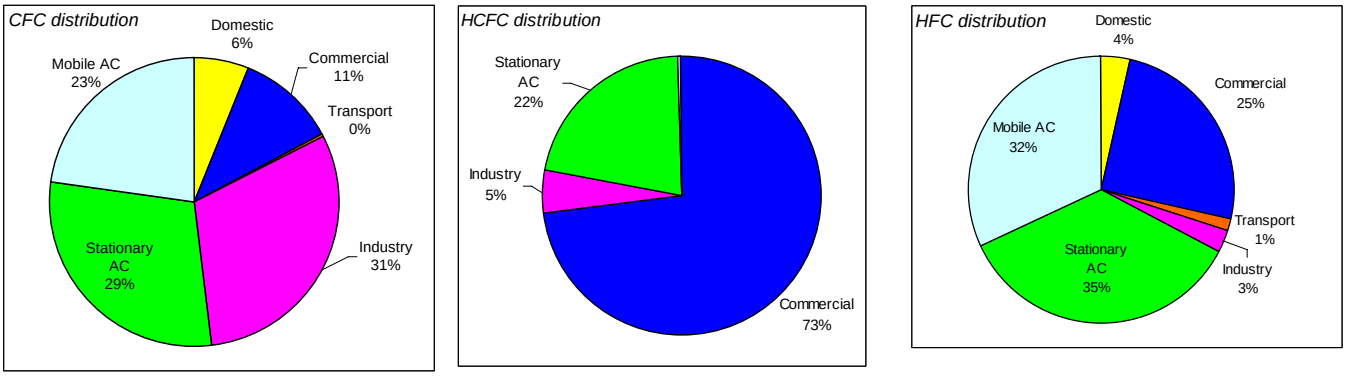


Figure 3.2: Refrigerant markets in 2015 - Scenario 1: Sector distribution.

Commercial refrigeration is the most important sector for the refrigerant demand in 2015, followed by the stationary AC and mobile AC sectors. If only HFC refrigerants are considered, air conditioning (both stationary and MAC) becomes the most important sector representing 2/3 of the total HFC markets. The refrigerant market for commercial refrigeration is 25 % of the total market.

The distribution over the different sectors remains more or less the same for each refrigerant market scenario.

3.2.3 Refrigerant markets by country groups

Table 3.3: Refrigerant markets in 2015 - Country distribution.

Market (tonnes)	Africa	C&S America	S&E Asia	N&W Asia	China
SC.1	20 085	68 008	85 640	42 635	394 832
SC.2	17 685 *-12%*	59 442 *-13%*	77 118 *-10%*	38 163 *-10%*	333 215 *-16%*
SC.3	16 039 *-20%*	51 319 *-25%*	69 440 *-19%*	34 695 *-19%*	289 621 *-27%*

Market (tonnes)	EU	East Europe	Japan	Oceania	USA
SC.1	102 742	31 228	50 607	11 925	309 890
SC.2	84 203 *-18%*	27 855 *-11%*	44 935 *-11%*	10 388 *-13%*	255 958 *-17%*
SC.3	73 295 *-29%*	23 661 *-24%*	38 688 *-24%*	8 383 *-30%*	229 236 *-26%*

In 2015, China would be the most important refrigerant market with a demand of nearly 400,000 tonnes in the business as usual scenario, followed by the U.S.A. (at a level of 300,000 tonnes). If only HFC refrigerants are considered (which are marketed in all non-Article 5(1) countries, the U.S.A. represents 46% of the total HFC market in 2015 in the business as usual scenario.

In 2015, 74 % of the HCFC market (mainly HCFC-22) is in China. Because of the HCFC phase-out in the developed countries, the HCFC-22 servicing market would represent 10% of the 2015 global HCFC market.

The amount of CFCs required for the servicing market will still be 10,000 tonnes in 2015 (in the business as usual scenario). Figure 3.3 shows that there is still a CFC demand in non-Article 5(1) countries in 2015 which is possibly covered by illegal imports.

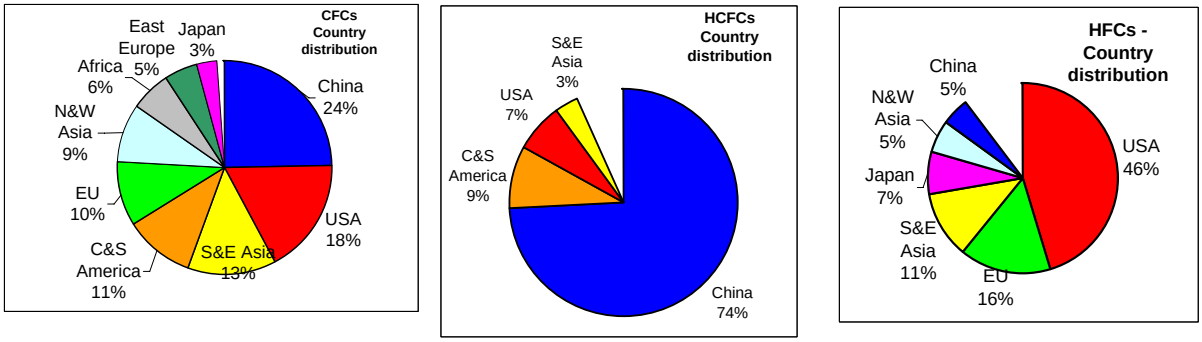


Figure 3.3: Refrigerant markets in 2015 - Scenario 1: Country distribution.

3.3 Results of projections to 2015: refrigerant banks

3.3.1 Refrigerant banks by type

Table 3.4: Refrigerant banks in 2015.

(tonnes)	CFCs	HCFCs	HFCs	HCs	Total
SC.1	103 769	1 791 370	2 297 873	13 025	4 206 037
SC.2	102 838	1 659 490	2 215 894	41 828	4 020 051
SC.3	101 276	1 491 239	2 082 504	60 467	3 735 486
ODP tonnes	CFCs	HCFCs	HFCs	HCs	Total
SC.1	82 124	71 132	-	-	153 256
SC.2	81 361	65 884	-	-	147 245
SC.3	80 105	59 139	-	-	139 245

The refrigerant bank will increase from 2.3 million tonnes in 2000 to 4.2 million tonnes in 2015 in the business as usual scenario. The HFC market would increase by a factor 5 in 15 years (2000 versus 2015). The policies aimed at the reduction of refrigerant emissions do not have a significant effect on the size of the refrigerant banks. In the scenario 3, the refrigerant banks would more or less stabilise at a level of 4 million tonnes in 2015 (if refrigerant NH_3 is included).

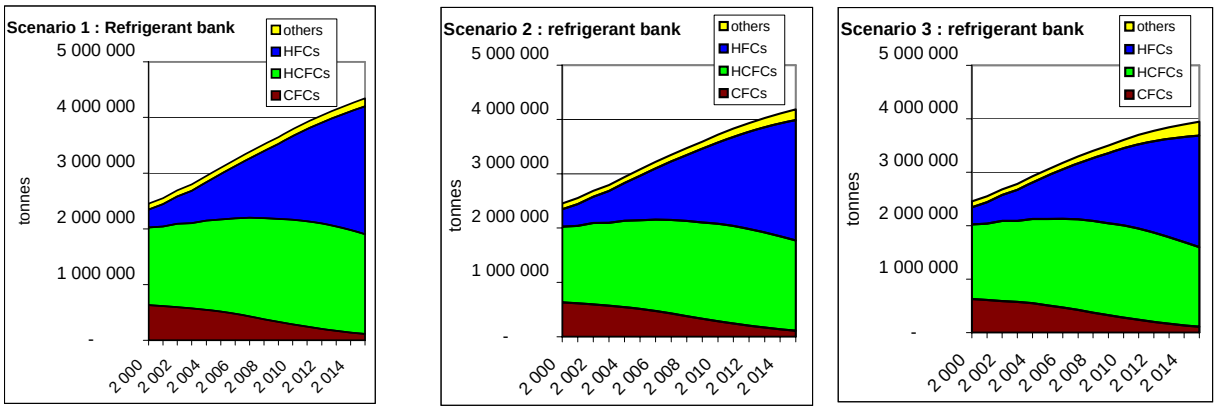


Figure 3.4: Evolution of refrigerant banks.

3.3.2 Refrigerant banks by sector

Table 3.5: Refrigerant banks in 2015 - Sector distribution.

bank (tonnes)	Domestic	Commercial	Transport	Industry	Stationary AC	Mobile AC
SC.1	239 256	1 193 236	23 210	355 665	1 857 926	675 923
SC.2	217 226 *-9%*	1 172 827 *-2%*	23 210 *0%*	344 326 *-3%*	1 785 640 *-4%*	641 510 *-5%*
SC.3	200 055 *-16%*	1 086 643 *-9%*	23 210 *0%*	331 132 *-7%*	1 691 315 *-9%*	611 059 *-10%*

ODP tonnes	Domestic	Commercial	Transport	Industry	Stationary AC	Mobile AC
sc1	30 362	35 456	157	18 429	59 289	11 481
sc2	29 603	35 365	157	18 416	54 282	11 474
sc3	28 724	32 827	157	18 103	50 116	11 443

The sector with the largest bank is stationary air conditioning with 1.8 million tonnes (42%) refrigerant banked in 2015 according to scenario 1. The HFC refrigerants are mainly found in the mobile air conditioning (28%) and stationary air conditioning (41%) sectors.

The HCFC refrigerants form the most important bank in commercial refrigeration, characterised by 0.75 million tonnes of HCFC-22 banked globally in 2015.

The CFC bank that remains in 2015 is estimated at about 110,000 tonnes. Most of the CFCs come from the domestic refrigeration (33%) and industrial refrigeration sectors. Equipment in these sectors has a relatively long lifetime and the emission rates are low. Containment allows increasing the time between serviced periods.

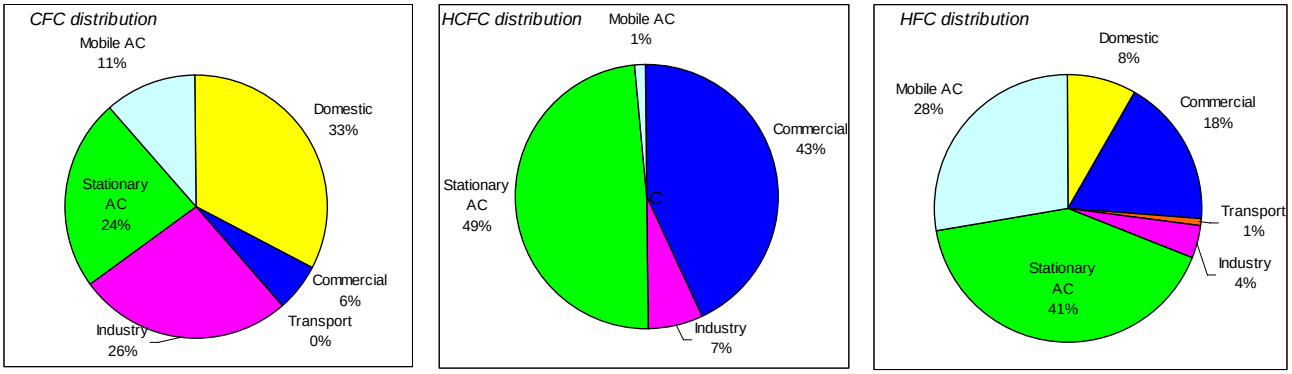


Figure 3.5: Refrigerant banks in 2015 - Sector distribution.

3.3.3 Refrigerant banks by country groups

Table 3.6: Refrigerant banks in 2015 - Country distribution.

Bank (tonnes)	Africa	C&S America	S&E Asia	N&W Asia	China
SC.1	82 964	249 012	372 410	191 598	1 130 290
SC.2	82 101 *-1%*	245 626 *-1%*	372 410 *0%*	189 499 *-1%*	1 123 664 *-1%*
SC.3	79 102 *-5%*	234 269 *-6%*	359 415 *-3%*	184 647 *-4%*	1 045 749 *-7%*

Bank (tonnes)	EU	East Europe	Japan	Oceania	USA
SC.1	471 980	125 681	248 352	50 161	1 422 768
SC.2	427 389 *-9%*	122 908 *-2%*	235 535 *-5%*	48 422 *-3%*	1 337 186 *-6%*
SC.3	393 816 *-17%*	116 152 *-8%*	221 589 *-11%*	43 020 *-14%*	1 265 655 *-11%*

In 2015, the USA will have the largest global refrigerant bank; furthermore, 43% of the HFC bank will be located in the USA. Nevertheless, in 2015, the most important HCFC bank would be located in China (53% of the total global bank).

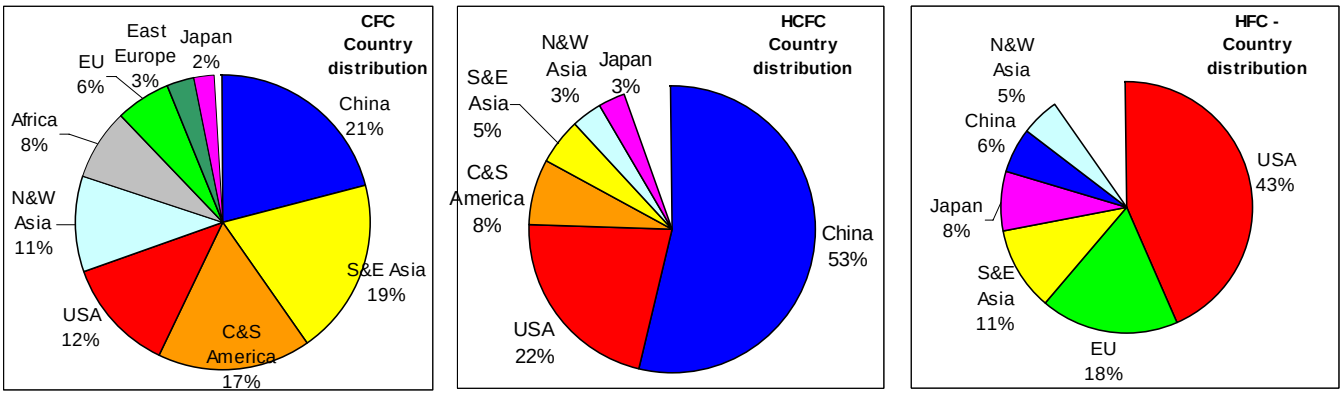


Figure 3.6: Refrigerant banks in 2015 - Country distribution.

3.4 Results of projections to 2015: refrigerant emissions

3.4.1 Refrigerant emissions by type

Table 3.7: Refrigerant emissions in 2015.

(tonnes)	CFCs	HCFCs	HFCs	HCs	Total
SC.1	24 585	455 028	365 719	525	845 857
SC.2	19 390	344 958	253 294	639	618 281
SC.3	14 369	258 928	161 761	687	435 744

In 2002, the refrigerant emissions are almost 470,000 tonnes if one would include 100,000 tonnes of HFCs. In the same year, HCFCs represent half the global refrigerant emissions. According to the business as usual scenario (sc1), the refrigerant emissions in 2015 would reach the 850,000 tonnes level with a high share of HFCs (42% of global emissions of all refrigerants). In the second scenario, the reduction of emission rates and the improvement of the recovery efficiency result in a reduction of total global refrigerant emissions, to a level of 620,000 tonnes.

In the third scenario, more efforts are done. Fugitive emissions are reduced thanks to better servicing and the installation of control devices on refrigerating equipment. Refrigerant recovery is generally applied in all sectors; the operators are assumed to be well qualified and equipped with adapted tools. In the period 2008-2010, the global emissions would reach their maximum value at 520,000 tonnes, and, following a decreasing trend, will be just below the 2002 level in 2015 (total emissions being 435,000 tonnes, see figure 3.7).

The increase in HFC emissions would be rather moderate to 60% in the third scenario (total HFC emissions being 160,000 tonnes).

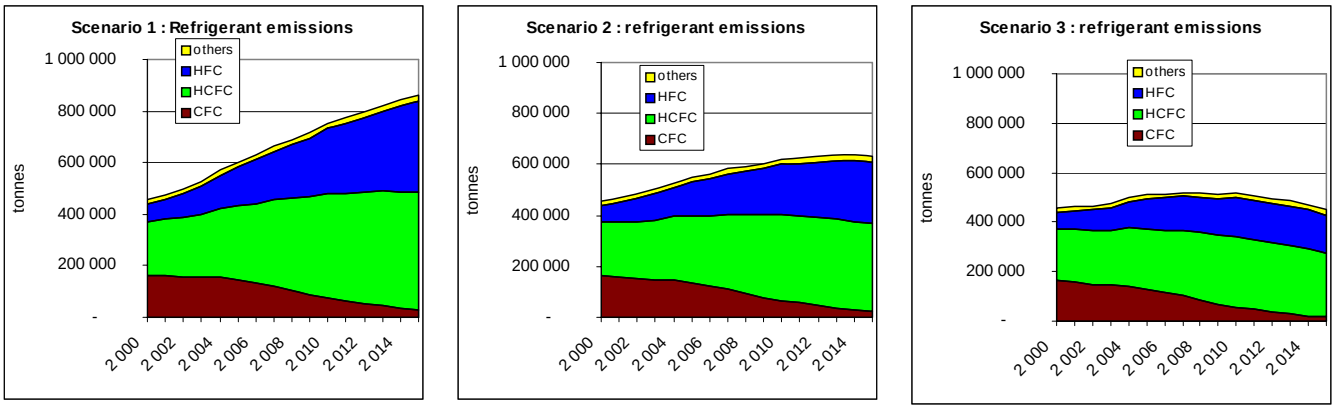


Figure 3.7: trends of refrigerant emissions.

3.4.2 Refrigerant emissions by sector

Table 3.8: Refrigerant emissions in 2015 - Sector distribution.

Emissions (tonnes)	Domestic	Commercial	Transport	Industry	Stationary AC	Mobile AC
SC.1	13 404	392 757	8 695	56 024	205 639	191 399
SC.2	9 284 *-31%*	300 155 *-24%*	7 278 *-16%*	48 186 *-14%*	142 873 *-31%*	133 564 *-30%*
SC.3	6 415 *-52%*	233 139 *-41%*	5 255 *-40%*	35 686 *-36%*	94 639 *-54%*	82 084 *-57%*

Commercial refrigeration is the most important contributing sector to the refrigerant emissions. 66% of all HCFC emissions originate in this sector. The emission rates are high and, in a large number of countries, the recovery is not effective.

The important contributing sector to HFC emissions is mobile air conditioning, where, in 2015, nearly half of all HFC emissions occur. Lower emission rates in stationary AC equipment make it possible to keep the HFC emissions in this sector at a level of 21% of all HFC emissions.

In 2015, CFC emissions are distributed evenly over the different sectors (stationary AC, MAC, domestic, commercial and industrial refrigeration). In 2015, the level of CFC emissions totals 3% of all refrigerant emissions.

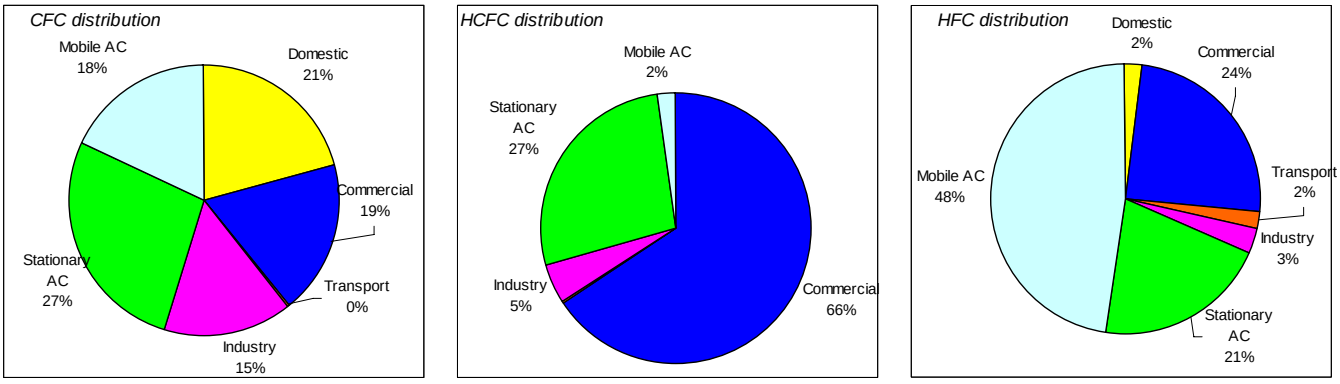


Figure 3.8: Refrigerant emissions in 2015 - Sector distribution.

3.4.3 Refrigerant emissions by country groups

Dependent on the actual level of the emission rates, and on the recovery efficiency, the efforts to reduce total refrigerant emissions are different in different countries. Countries are characterised by different economic growths and by unequal access to improved technologies.

Table 3.9: Refrigerant emissions in 2015 - Country distribution.

Emissions (tonnes)	Africa	C&S America	S&E Asia	N&W Asia	China
SC.1	15 759	54 519	67 795	30 881	313 423
SC.2	12 773 *-19%*	44 578 *-18%*	54 930 *-19%*	24 691 *-20%*	249 027 *-21%*
SC.3	10 163 *-36%*	33 270 *-39%*	38 789 *-43%*	17 725 *-43%*	198 579 *-37%*

Emissions (tonnes)	EU	East Europe	Japan	Oceania	USA
SC.1	78 080	24 598	39 324	8 417	235 028
SC.2	48 824 *-37%*	20 537 *-17%*	27 744 *-29%*	5 615 *-33%*	152 526 *-35%*
SC.3	29 110 *-63%*	15 289 *-38%*	15 543 *-60%*	3 381 *-60%*	95 288 *-59%*

In 2015, the enormous economic development of China would bring this country to the top of the list where it concerns refrigerant emissions, before the USA. In China, more than 300,000 tonnes of refrigerant will be emitted in this year (this equals 35% of global refrigerant emissions).

In 2015, HCFCs are generally used to an important degree in the Article 5(1) countries, following the progressive phase-out of CFCs.

In 2015, the non-Article 5(1) countries will emit 90% of total HFC emissions. The major part (44%) is emitted in the USA where mobile air conditioning equipment has been widely developed.

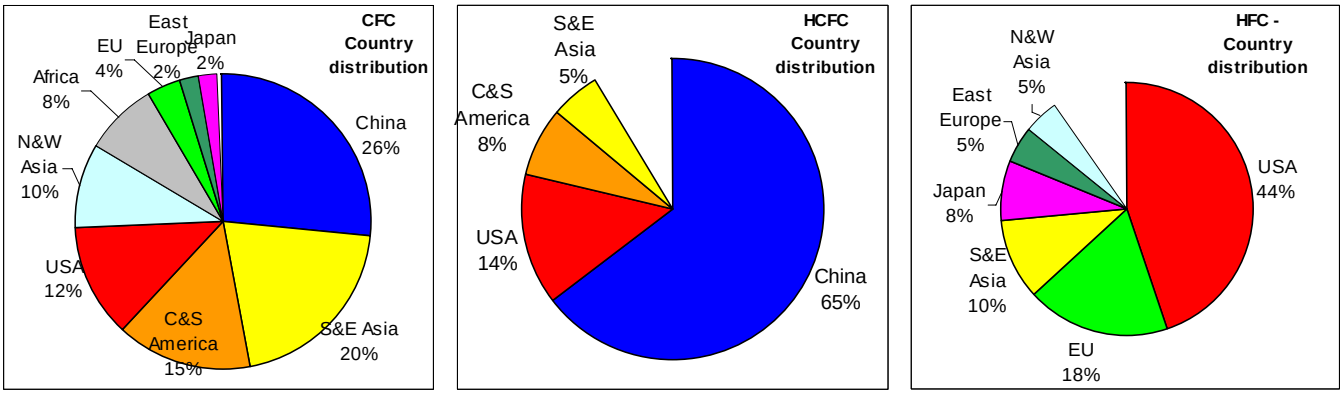


Figure 3.9: Refrigerant emission in 2015 - Country distribution.

3.5 Results of projections to 2015: equivalent CO_2 emissions

3.5.1 Refrigerant emissions by type

Table 3.10: Refrigerant $CO_{2equiv.}$ Emissions in 2015 (2nd assessment report IPCC).

ktonnes CO_2	CFCs	HCFCs	HFCs	HCs	Total
SC.1	186 664	673 520	667 007	10	1 527 201
SC.2	148 967	512 339	452 833	13	1 114 152
SC.3	111 234	385 666	286 837	14	783 750

Via the progressive phase-out of CFCs, which generally have higher GWP than the equivalent HCFCs and HFCs, the global equivalent CO_2 emissions will decrease in spite of the increase in emissions in absolute terms. In the business as usual scenario, the global

level of equivalent CO_2 emissions remains more or less constant over the period 2002-2015 and is at the same level of 1.5 billion tonnes of CO_2 in 2002 and 2015.

If only HFC refrigerants are considered, the emissions increase from 180 million tonnes CO_2 equivalent to 670 million tonnes in 2015 (in the BAU scenario). In the second scenario, the HFC CO_2 equivalent emissions reach a level of 450 million tonnes. In the lowest emission scenario total HFC emissions are at the level of 286 million tonnes CO_2equivalent.

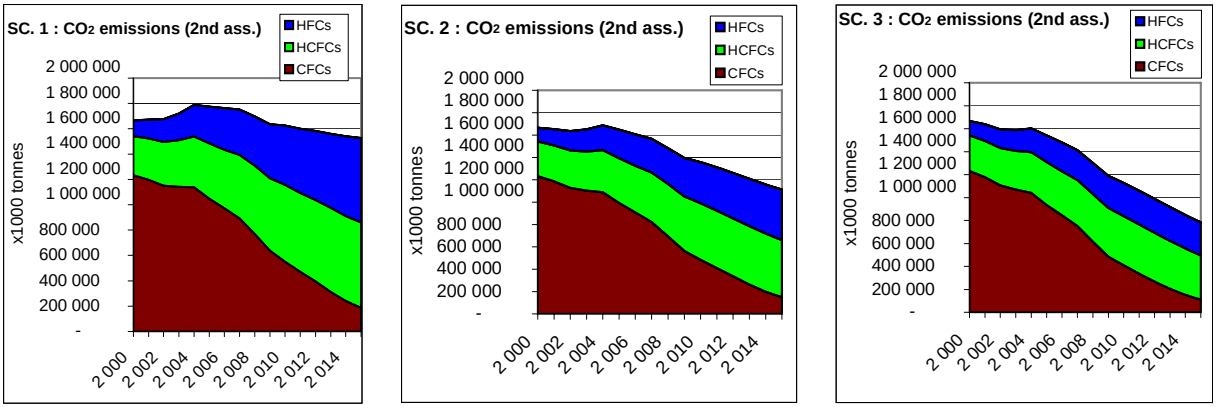


Figure 3.10: Evolution of refrigerant CO_2 equivalent emissions.

3.5.2 Refrigerant emissions by sector

Table 3.11: CO_2 equivalent emissions in 2015 - Sector distribution.

Em CO_2 (ktonnes)	Domestic	Commercial	Transport	Industry	Stationary AC	Mobile AC
SC.1	51 318	758 869	22 195	91 266	322 788	280 766
SC.2	37 399 *-27%*	560 011 *-26%*	18 612 *-16%*	77 516 *-15%*	225 172 *-30%*	195 446 *-30%*
SC.3	27 191 *-47%*	418 624 *-45%*	13 280 *-40%*	55 794 *-39%*	149 640 *-54%*	119 229 *-58%*

The use of higher GWP refrigerants in low temperature refrigeration applications has a direct impact on their relative part in the emissions in CO_2 equivalent. For example, the share of HFC emissions from commercial refrigeration amounts to only 24% of the total, however, if converted to equivalent CO_2 emissions, it is the most important emissive sector, where 45% of the total HFC equivalent CO_2 emissions takes place.

In 2015, the HCFC emissions would represent almost 50% of the total of the refrigerant equivalent CO_2 emissions. Two thirds of the HCFC emissions originate from the commercial refrigeration sector. In 2015, independent of which scenario is considered, commercial equipment would produce more than half of the refrigerant equivalent CO_2 emissions.

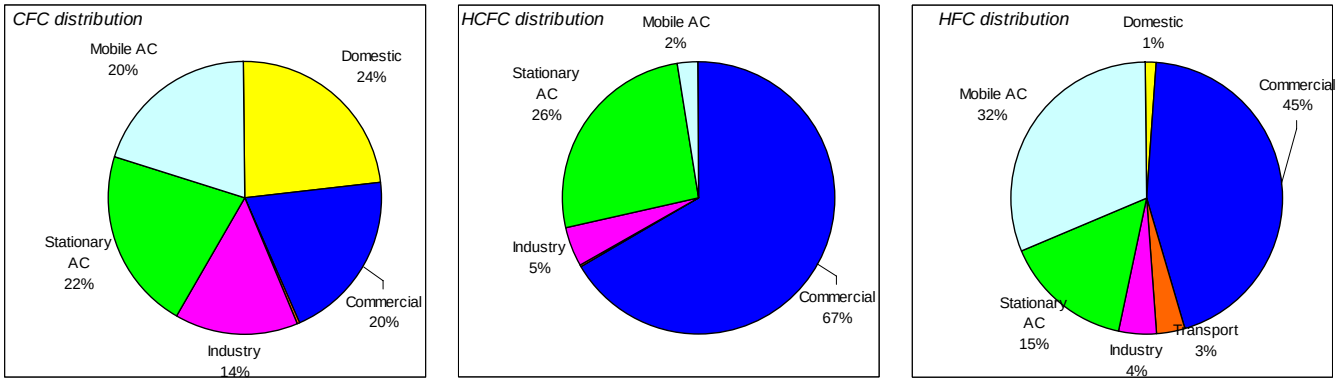


Figure 3.11: CO_2 equivalent emissions in 2015 - Sector distribution.

3.5.3 Refrigerant emissions by country group

Table 3.12: CO_2 equivalent emissions in 2015 - Country distribution (ktonnes).

CO2 em. (kt)	Africa	C&S America	S&E Asia	N&W Asia	China
SC.1	34 696	99 343	148 514	66 747	504 444
SC.2	28 340 *-18%*	80 245 *-19%*	118 607 *-20%*	52 580 *-21%*	401 908 *-20%*
SC.3	22 696 *-35%*	59 960 *-40%*	86 086 *-42%*	38 454 *-42%*	318 258 *-37%*

CO2 em. (kt)	EU	East Europe	Japan	Oceania	USA
SC.1	142 051	53 251	64 704	14 387	398 306
SC.2	83 790 *-41%*	43 877 *-18%*	44 276 *-32%*	9 297 *-35%*	250 460 *-37%*
SC.3	44 536 *-69%*	33 027 *-38%*	23 797 *-63%*	5 304 *-63%*	150 962 *-62%*

The emission distribution over the countries in CO_2 equivalents is nearly the same as the refrigerant emission distribution (compare Figure 3.9 and 3.12). Because reduction emission policies are easier to apply in developed countries, the part of equivalent CO_2 emissions that can be attributed to Article-5(1) countries (and particularly China) increases in both the second and the third scenario.

In 2015, the share of the equivalent CO_2 emissions in China (calculated for all refrigerants) would increase from 35% (in scenario 1) to 40% (in scenario 3) relatively spoken. In the developed countries the trend is reversed, in the USA a decrease from 27% (in scenario 1) to 19% (in scenario 3) takes place. The relative contribution of the EU countries decreases from 9 % (in scenario 1) to 6 % (in the best scenario, 3).

Scenario 3 is a clear demonstration of the impact of both emission reduction policies and choices for low GWP refrigerants.

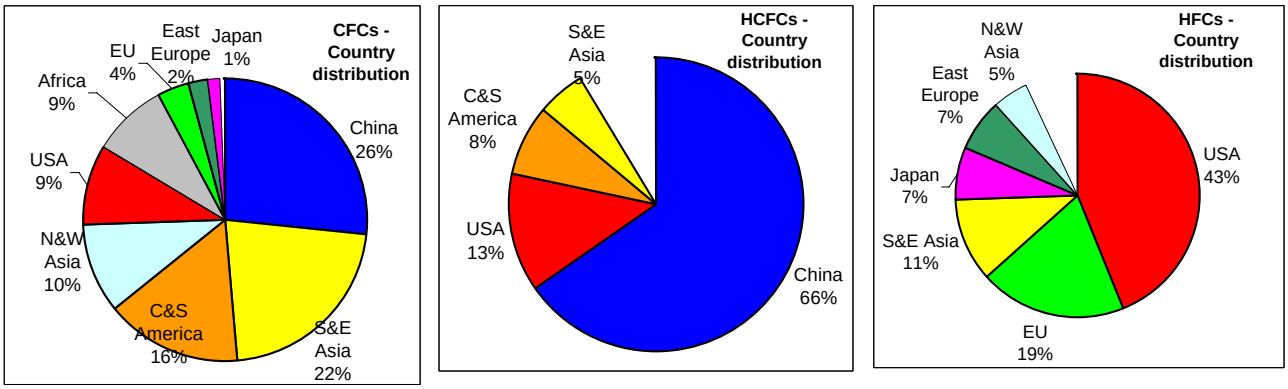


Figure 3.12: CO_2 equivalent emissions in 2015 - Country distribution.

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