Proklima

Global banks of ozone depleting substances

A country-level estimate

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

of the Federal Republic of Germany

As a federally owned enterprise, GIZ supports the German government in achieving its objectives in the field of international cooperation for sustainable development.

Published by:
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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Bonn and Eschborn, Germany

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Programme/project description:
Management and Destruction of Existing Ozone Depleting Substances Banks/Proklima

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GIZ is responsible for the content of this publication.

Printing and distribution:
Druckriegel GmbH, Frankfurt

Printed on 100% recycled paper, certified to FSC standards.

Eschborn, 2017

Serial number:
G-S05-2017-en-01

Content

Abbreviations

BMUB	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
CFC	Chlorofluorocarbon
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HPMP	Hydrochlorofluorocarbon Phase Out Management Plan
HS	Harmonised system
ICI	International Climate Initiative
IPCC	International Panel on Climate Change
MLF	Multilateral Fund for the Implementation of the Montreal Protocol
MRV	Monitoring, reporting and verification
ODP	Ozone depleting potential
ODS	Ozone depleting substances
RAC	Refrigeration and air-conditioning (sector)
RTOC	Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee
TEAP	Technology and Economic Assessment Panel
TBM	Transboundary Movement
UNFCCC	United Nations Framework Convention on Climate Change
WEEE	Waste Electrical and Electronic Equipment
XPS	Extruded Polystyrene

1 Background

This paper is part of the project 'Management and Destruction of Existing Ozone Depleting Substances Banks' funded by the German Federal Ministry for Environment, Nature Conservation, Building and Nuclear Safety (BMUB) under its International Climate Initiative (ICI) and implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The paper aims to assess the climate impact of existing ozone depleting substances (ODS) banks and draw attention to the political need for measures to collect and destroy ODS banks. The results of this analysis will be used to develop international guidance on ODS bank management. Policy analysis and selected activities to improve the ODS bank management in 5 partner countries provide experiences from the field that are fed back into several guidelines.

To highlight the magnitude of the emissions potentially caused by ODS banks and to put them into perspective, a top-down estimate was conducted of ODS banks for the five most widely used ODS in refrigeration, air-conditioning and foam[1] (CFC-11, CFC-12, HCFC-22, HCFC-141b and HCFC-142b). The approach presented in this paper is new as it uses a country-based calculation to determine bank estimates on a country-level and make projections for the future. The aim is to break down the global challenge by providing estimates for individual countries, which will also be useful for raising awareness on the complex issue of ODS bank management on the country level.

1 Halons are not included because their management is organised in so-called halon bank initiatives, which reclaim large quantities of halon for existing long-term essential needs, such as civil aviation.

2 Results

In 2014, global ODS banks were estimated to comprise 5,687 kt ODS (equal to 9.9 Gt CO_2eq) in total (Figure 1). The projection until 2020 shows that ODS banks are presently declining. After a peak in 2000 at 19.0 Gt CO_2eq, only 5.0 Gt CO_2eq will remain by 2020 (Figure 2). A detailed description of the calculation methodology is provided below.

In comparison, TEAP 2009 estimated a reachable bank of 5,354 kt ODS for 2010 alone, which translates to 16.6 Gt CO_2eq mitigation potential that year. TEAP's dataset provides accumulated data on halons, CFC and HCFC used in refrigeration and air conditioning (RAC) and foam. Our calculation estimates 6,409 kt ODS, equivalent to 13.2 Gt CO_2eq.

Since ODS are widely replaced by high GWP HFCs, the overall amount of refrigerants and blowing agents in the RAC and foam sector remain at a high level until 2050. While the ODS bank is projected to decline, the HFC banks will increase. Fast action is necessary to realise the highest impact and develop economies of scale.

Figure 1: Global ODS banks in kt ODS

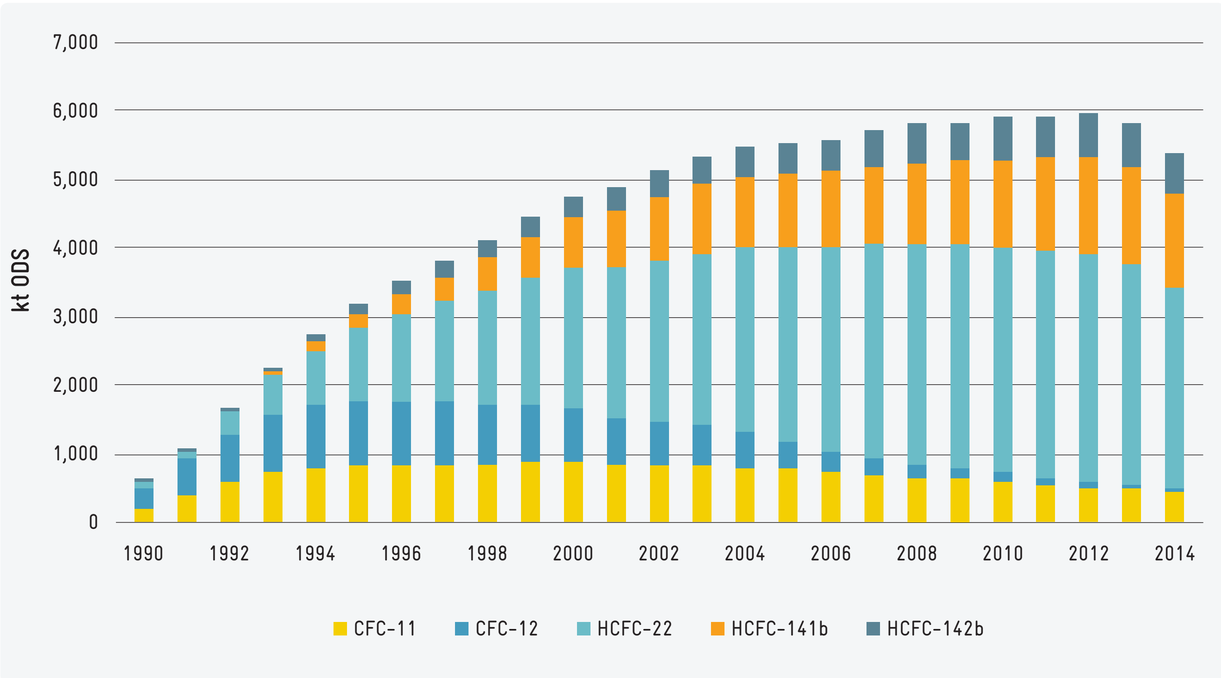
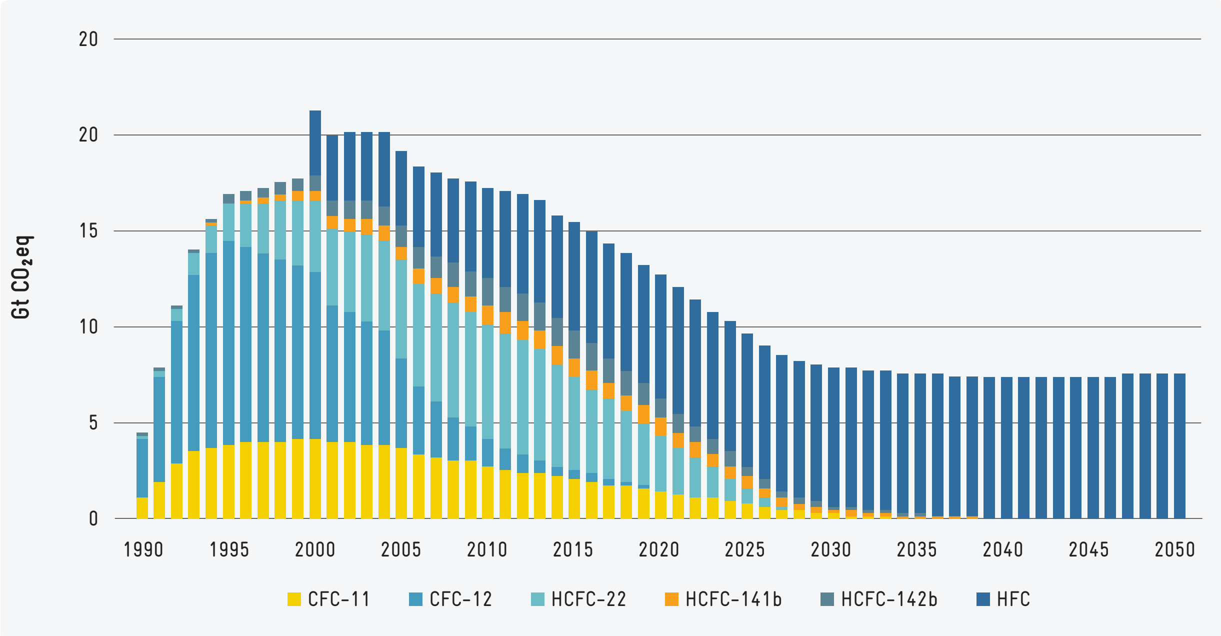


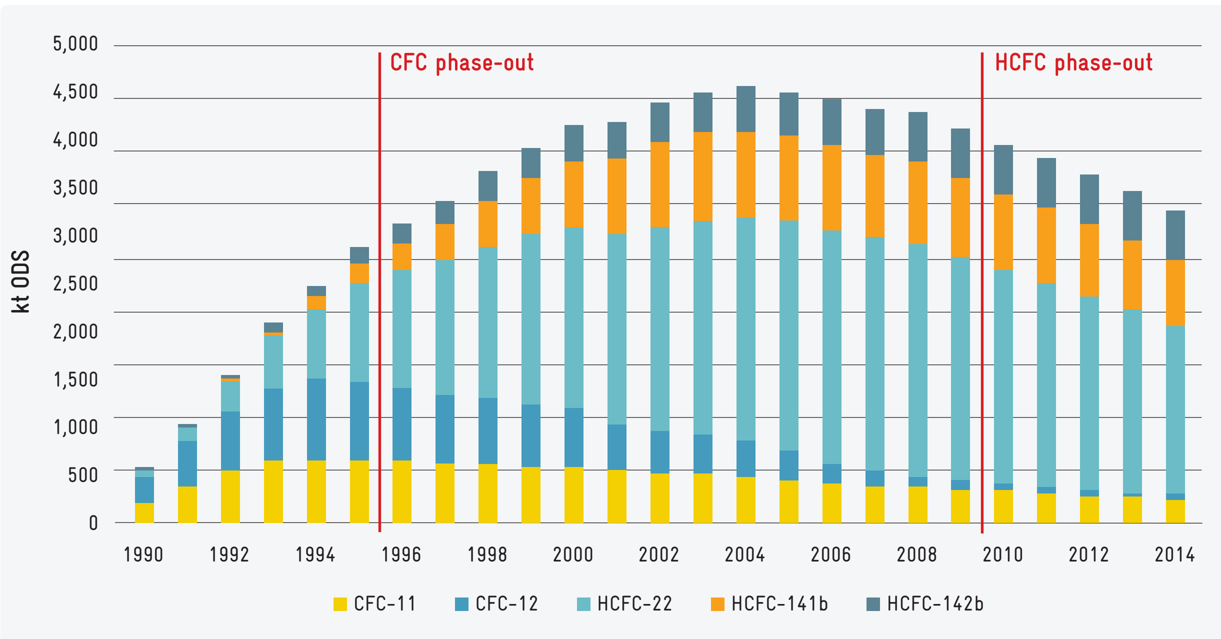
Figure 2: Global ODS and HFC banks in Gt CO_2eq



2.1 Non-Article 5 countries

Total banks amounted to 3,070 kt ODS in 2014 (Figure 3). As a result of previous CFC and HCFC phase-outs, ODS banks peaked in 2004 and declined thereafter.

Figure 3: ODS banks in non-A5 countries in kt ODS



2.2 Article 5 countries

The figures below illustrate an in-depth analysis of existing ODS banks in Article 5 countries.

In 2014, the total ODS banks in A5 countries amounted to 2,617 kt, with 42% attributed to the RAC sector and 56% to the foam sector.

As shown in Figure 4, the total amount in the banks peaked in 2013, when banks of HCFC-22 and HCFC-141b started to decline. About half of the ODS banks are made up of HCFC-22, the dominant ODS in the RAC sector.

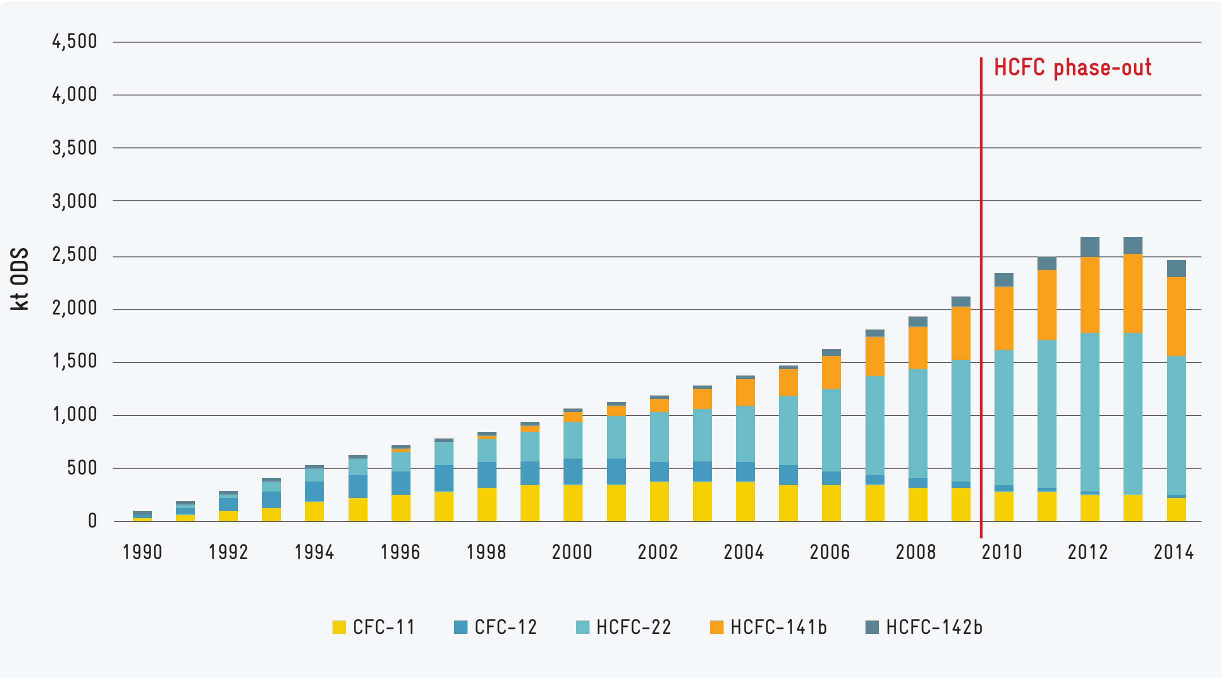
The decline of CFC banks is primarily a result of the CFC phase-out, which was completed in 2010. The CFC bank peaked in 2002. Due to the substitution of CFC by HCFC, the HCFC bank built up until 2013. Action is urgently needed to prevent emissions from the remaining bank.

The countries with the largest ODS banks are shown in Figure 5. China dominates the ranking, representing 50% of the total banks of Article 5 countries. The approach might underestimate the export of pre-charged equipment, resulting in overestimated ODS banks. In particular the results from countries with significant manufacturing capacity for export are affected, such as China.

Expressed in CO_2 equivalents, ODS banks of Article 5 countries in 2014 amounted to 4.6 Gt CO_2eq. Based on the trend of recent years and the resulting shift away from ODS use, ODS banks are projected to decline until 2020.

HFC banks data[2] were added from 2010 onwards and show how banks will shift to HFCs in the future and reach a level in 2020 equivalent to more than 50% of the combined bank.

Figure 4: ODS banks in A5 countries



2 Data provided by the Green Cooling Initiative

Figure 5: Article 5 countries with the highest calculated ODS bank

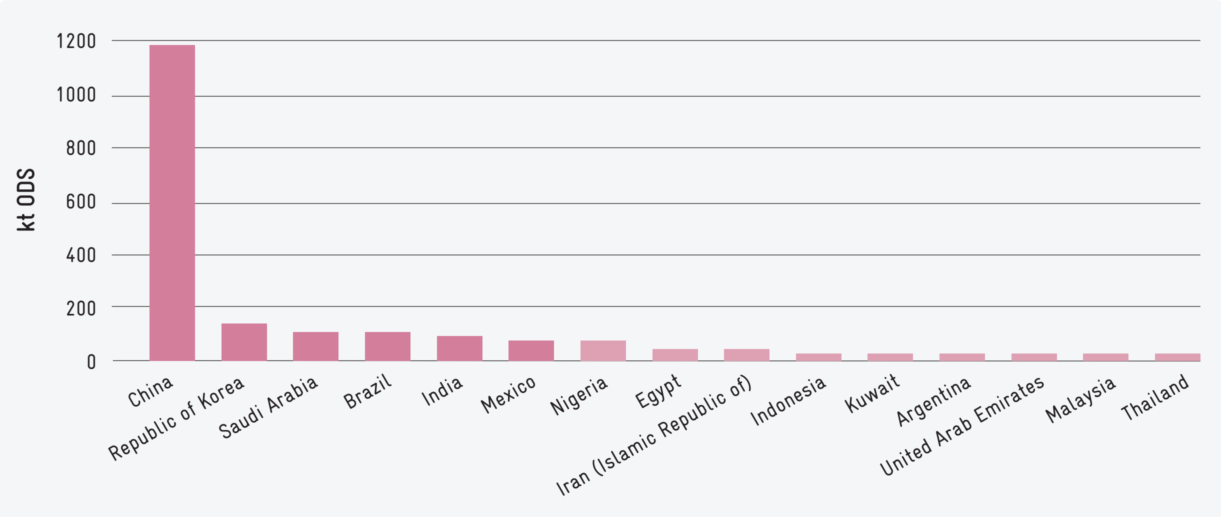


Figure 6 shows that bank management is not an issue that is resolved with declining amounts of ODS, but rather remains important in terms of reducing GHG emissions from HFCs.

The average equipment's lifetime is assumed to be 20 years; the waste stream of CFC-12 resulting from the decommissioning of equipment in Article 5 countries is modelled to begin in 2010, which is 20 years after the reporting of consumption was initiated. The amount of ODS contained in equipment being scrapped is projected to increase in the coming years, creating a window of opportunity to collect and destroy (or recycle) ODS to prevent emissions totalling 708 Mt CO_2eq between 2018 and 2020 (Figure 7).

Figure 6: ODS and HFC bank in A5 countries

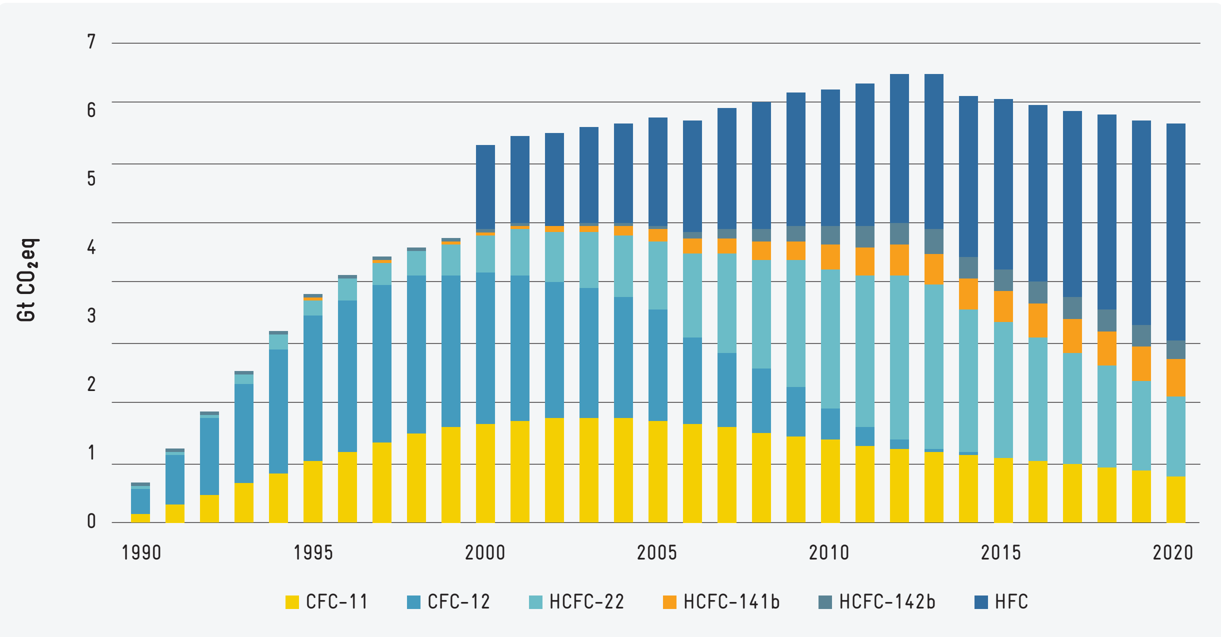
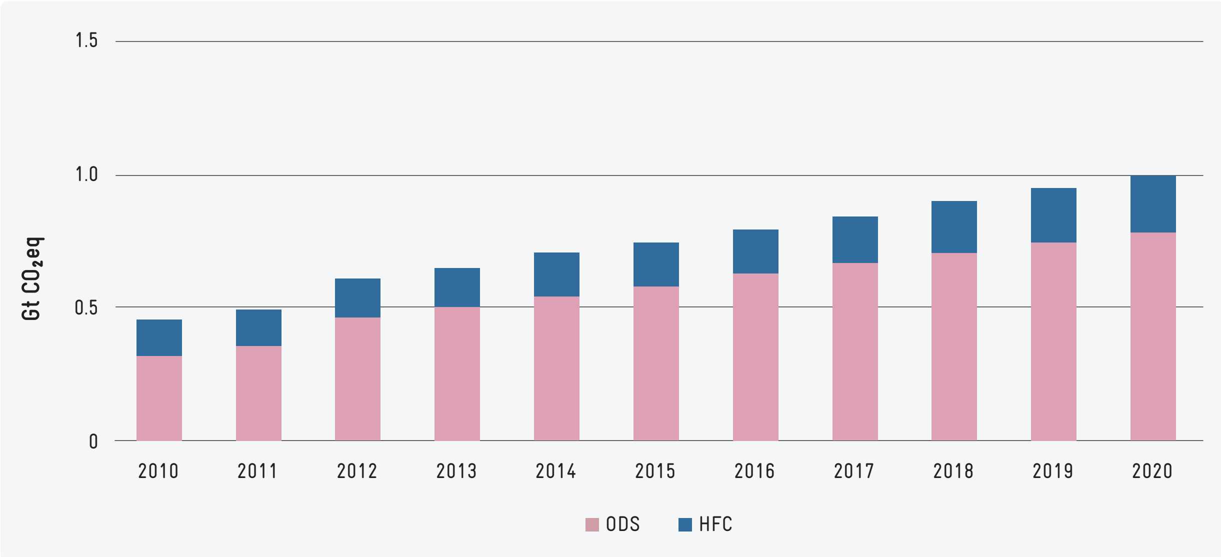


Figure 7: ODS and HFC waste stream A5 countries



3 Managing ODS banks in Article 5 countries

The aim of ODS banks management is to contain the gases and ultimately reuse or destroy the ODS as well as HFC in the future.

The amount of ODS/HFC contained in units reaching their end of life is the amount annually available for recovery, and it is potentially lost when not adequately treated.

For Article 5 countries, the annual amount of ODS contained in the waste stream is about 0.2 Gt CO_2eq. This amount is emitted if not recovered. Until 2025, the potential mitigation is about three times the estimated reduction from the HCFC Phase-out Management Plans[3] (HPMPs).

Figures 8 and 9 illustrate these estimates.

Figure 8: Potential end-of-life emissions from ODS bank and estimated emission reduction due to HPMP activities

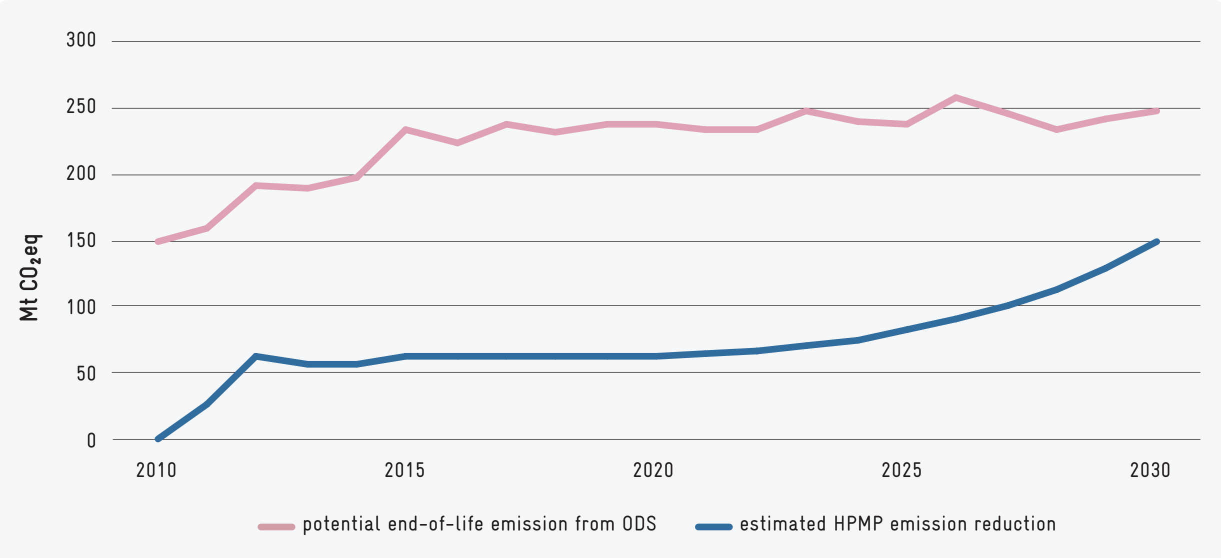
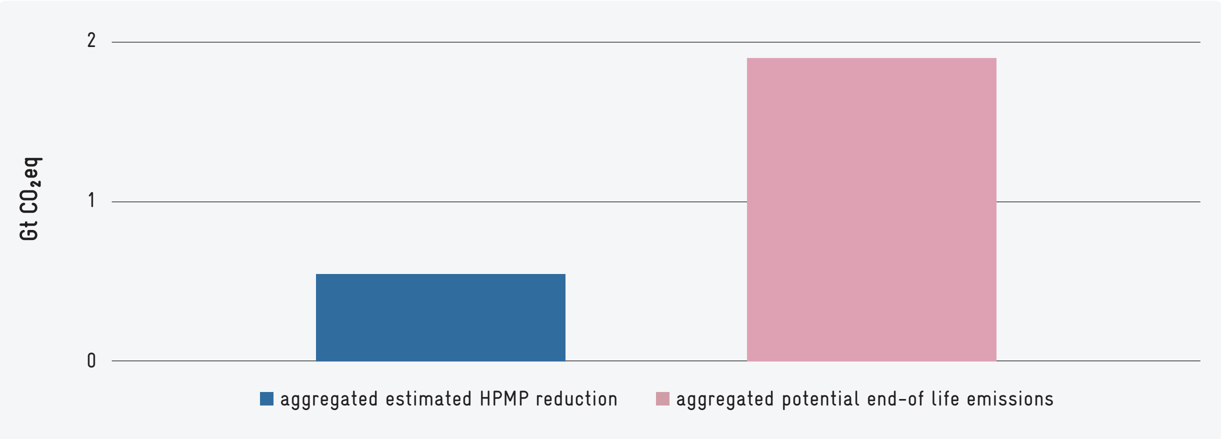


Figure 9: Aggregated potential emissions savings from HPMP activities and ODS bank management (2018-2025)



3 The emission reduction through the HPMP is estimated by comparing the average GWP of 2010 (i.e. before HPMP activities started) with the GWP resulting from the phase-out schedule.

3.1 Costs of ODS/HFC recovery and disposal

The costs for collecting ODS and HFCs from equipment and products vary greatly depending on the effort required. In case of low to medium effort and according to the Technology and Economic Assessment Panel (TEAP 2009b and ICF 2010), the total costs for refrigerant recovery, transport and disposal from large installations are 9 – 13 USD/kg, from stationary AC 10 – 34 USD/kg, and from domestic and commercial refrigerators 27 – 45 USD/kg for the refrigerant and 37 – 65 USD/kg for the blowing agent[4].

However, the study does not take into account situations where

- refrigerant recovery is obligatory
- recycled gases are normally returned to refrigerant distributors
- transport of returned bottles from distributors to filling stations is already occurring

The collection of refrigerants can be organised through the existing distributors' network without substantial funding. A similar approach can be taken where appliances are distributed through doorstep delivery systems, which is the case with many large stores that sell appliances.

The key issues are the existence of respective legislation and its enforcement. This type of practice already exists in many developed countries such as the EU, Australia and the US.

Financing the collection of ODS

The return of recycled refrigerants can be made obligatory through regulation. In this case, the refrigerant distributors, producers and importers need to share the costs. In exceptional cases, they can be allowed to charge a symbolic fee for returned refrigerants. However, the fee should be capped to avoid creating a disincentive for technicians to return used refrigerants. Deposit-and-refund schemes, where money is refunded for returned refrigerants, can be funded through a levy or fee on the sale of virgin ODS/HFC refrigerants.

Funding could also be organised based on an Extended Producer Responsibility (EPR) scheme. Such schemes distribute the costs of recycling according to the market share of importers and producers for refrigerants or appliances. Some international funds such as the Multilateral Fund (MLF), Global Environmental Facility (GEF), development banks, the UN, and bilateral agencies aid on setting up and managing EPR schemes.

3.2 Key elements of responsible ODS/HFC management

Promote onsite recycling

In general, a refrigerant that is contained in a working system can be reused after onsite recycling is conducted, including dehumidification and oil separation. For this purpose, recycling units are in the market and provided in part through activities funded under the MLF. This practice will minimise emissions, waste and costs. It only requires additional effort to obtain a recovery unit and cylinder. The equipment will not suffer from any deterioration because the recycled charge will be dehumidified and cleaned of dirt and oil.

4 More information on costs are provided in the study 'Management and destruction of existing ozone depleting substances banks' and in the cited publications.

Use of reusable cylinders.
Allowing only reusable cylinders for refrigerants enables technicians to return excess or unusable refrigerants to the distributor. One-way cylinders should be banned, because they cannot be reused and undermine efforts for recovery.

Adopt a take-back obligation with a deposit-and-refund scheme
Take-back obligations are currently either implemented at no cost (e.g. France) or with a permitted charge (e.g. Germany). The best solution is if technicians and distributors are somehow compensated for their participation, or if reclaimed refrigerants are only sold to those returning an equal amount of collected refrigerants. Funding would be supported through a levy or fee for the sale of virgin ODS/HFC.

Best practice examples on ODS and HFC bank management involving EPR schemes can be found in member states of the European Union (EU) and Australia, among others. While the organisation of the schemes varies greatly, a common feature is that costs for recovery, collection and reclamation/destruction are covered by producers and distributors. After studying several schemes, in 2016 the Environmental Investigation Agency stipulated key elements of national EPR schemes for the recovery and recycling, reclamation or destruction of ODS and HFCs.

Ensure accessible collection points for refrigerants or waste appliances
Without collection points that are easily accessible to technicians, take-back obligations alone are not effective. This aspect particularly depends on country-specific infrastructure, and cooperation with other waste recycling schemes should be explored.

Ensure reclamation and destruction facilities
Producers can assist in reclamation and destruction, if it is mandatory. Funding can be organised through a collective industry association (as e.g. in Australia) or through a government organisation.

From the perspective of resource efficiency, reclamation of refrigerants should be given priority over destruction except where there is no demand anymore. HCFC and HFC refrigerants contain Fluor which is a raw material whose natural deposits are limited. Only substances that cannot be reclaimed are to be destroyed.

Recycling and reclamation procedures range from simple cleaning to distillation columns, which enable separation of different substances contained in a mixture and reduce the waste stream. Reclamation of refrigerants may be more cost effective than destruction and provides an incentive for reselling reclaimed refrigerants.

Building a quality infrastructure based on informed decision-making
Further guidance on sound ODS banks management can be found in the documents and guidelines developed under this project:

- The Gap Analysis compares the status quo of ODS banks management in specific countries in terms of existing policy frameworks, financing options, the effectiveness of collection and recycling or access to destruction, and includes a best practice example. The assessment helps countries in specifying their needs for support.

- The global roadmap provides a framework for all activities in this area and includes a step-by-step guide for the improvement of ODS banks management.

- Several guidelines provide detailed know-how on various aspects of ODS bank management:
  - The Tier 1 approach developed for the global calculation could be easily adopted for each individual country. With increasing experience and additional information on the sectoral use of ODS, the assumptions made could be targeted to specific countries and provide a better estimate of the existing ODS bank.
  - Guideline to conduct an ODS bank inventory.
  - Guideline on policy measures for the management and destruction of ozone depleting substances.
  - Guideline to establish a collection system for equipment containing ODS.
  - Guideline for the transboundary movement of ODS waste.
  - Management and Destruction of Existing Ozone Depleting Substances Banks.

4 Next steps

This study aims to foster a global dialogue on best practices in managing ODS banks and on guidelines and effective steps to prevent emissions from banks. The ODS banks estimate provided is based on the reporting under Article 7 by countries operating under the Montreal Protocol. Further research should be conducted to monitor and amend additional data on ODS/HFC stocks and emissions from other sources, such as appliance sales statistics, containment practices, recovery procedures, etc.

The findings of the analysis and excessive emissions from ODS/HFC that are contained in existing banks point to the urgency to act quickly. Every day nearly 1 Mt CO_2eq of ODS and HFC are emitted, but a substantial percentage of this could recovered. With the increasing consumption of high-GWP HFCs, GHG emissions from the banks will increase annually.

As a first step, we recommend to set-up an international registry of ODS/HFC banks under the Montreal Protocol. Reporting could be performed when parties submit their Article 7 data. For assessment and reporting of banks, several tools have been developed that will enable countries to understand and develop their ODS banks inventories.

The Tier 1 approach used thus far under the MP for assessing ODS/HFC consumption could be amended by applying country-specific assumptions on sectoral use, typical leak rates and equipment lifetimes to reflect annual emissions. With growing experience, the accuracy of this data will improve. An even more sophisticated approach is the Tier 2 approach as applied in the national communication of parties under the UNFCCC. Both approaches are described in detail in the 'Guideline to conduct an ODS bank inventory' (GIZ 2017).

A number of economic feasible activities could be implemented by parties at reasonable cost. For example, regulations could obligate technicians to use reusable cylinders, to recycle and reuse refrigerants onsite, and to hand in unusable refrigerants to distributors for take back, reclamation or destruction. In return, refrigerant distributors could reward the handing in of unusable refrigerants with lower priced refrigerants from reclamation. This kind of cooperation among the producers, importers and distributors is already obligatory in most industrialised countries today.

National authorities can either place the financial responsibility on the producers directly or through collective industry associations. Enhanced responsibility of producers and distributors can also be supported through simple measures, such as charging a levy on the sale of virgin refrigerants or new equipment that compensates for the obligatory take back of unusable refrigerants and equipment.

Reclamation, is the cheapest solution, should be prioritised over destruction. If a framework is established it can work very well in developing countries as reclaimed refrigerants can be sold at reasonable prices.

Nevertheless, it is very difficult for developing countries to act in isolation. Therefore, concerted political action on international level is needed to effectively support governments and initiatives that are seriously interested in reducing emissions from ODS/HFC banks on a broader scale. In view of current international discussions, a registry would be just the first step before pursuing others.

5 References

Gamlen P.H., Lane B.C., Midgley P.M. and Steed J.M (1986). The production and release to the atmosphere of $CFCl_3$ and CF_2 Cl_2 (chlorofluorocarbons CFC-11 and CFC-12). Atmos. Environ. 20: 1077–1085.

Green Cooling Initiative, www.green-cooling-initiative.org

GIZ, 2017. Guideline to conduct an ODS bank inventory. Eschborn, Germany

EIA, 2016. National Producer Responsibility Schemes under the EU F-gas Regulation, Briefing Note.

ICF, 2010. Identifying and Assessing Policy Options for Promoting the Recovery and Destruction of Ozone Depleting Substances (ODS) and Certain Fluorinated Greenhouse Gases (F-Gases) Banked in Products and Equipment. Prepared for the European Commission.

IPPC, 2006. Guidelines for National Greenhouse Gas Inventories, Volume 3: Industrial Processes and Product Use.

RTOC, 1998. Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee 1998 Assessment. Coordination: Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee, UNEP Nairobi.

TEAP, 1997. April 1997 Report of the Technology and Economic Assessment Panel Volume 1. Coordination: Technology and Economic Assessment Panel, UNEP Nairobi.

TEAP, 1998. Assessment Report of the Technology and Economic Assessment Panel. Coordination: Technology and Economic Assessment Panel, UNEP Nairobi.

TEAP, 2009. Task force decision XX/7 – Interim Report 'Environmentally sound management of banks of ozone-depleting substances'. Coordination: TEAP and its XX/7 Task force. UNON Nairobi.

TEAP, 2009b. Task force decision XX/7 – Phase 2 Report 'Environmentally sound management of banks of ozone-depleting substances'. Coordination: TEAP and its XX/7 Task force. UNON Nairobi.

UN COMTRADE database accessed via https://wits.worldbank.org/WITS/, last access: 16.2.2016.

US EPA, 2011. Construction and Demolition, How to Properly Dispose of Refrigeration and Air-Conditioning Equipment. United States Environmental Protection Agency https://www.epa.gov/sites/production/files/documents/ConstrAndDemo_EquipDisposal.pdf, last access: 14.3.2017.

WEEE Forum, 2007. Requirements for the Collection, Transportation, Storage, Handling and Treatment of Household Cooling and Freezing Appliances containing CFC, HCFC or HFC, http://www.weee-forum.org/system/files/services/cfc_standard_0.pdf, last access: 14.3.2017.

6 Annex: Methodology

6.1 Data sources

The ODS bank estimate is based on consumption data which are available as a result of the reporting obligations under Article 7 to the Montreal Protocol.

The consumption data accounts for bulk production, import, and export of ODS in accordance with the definition of consumption under the Montreal Protocol[5]. The consumption was attributed to RAC and foam as the main ODS consuming sectors, as well as 'other', which represents all uses that lead to instant emission and thus do not build a bank. Such uses include aerosols, solvents, agents for sterilisation, process agents, metered dose inhalers etc.

For the attribution of CFCs, reports from TEAP (1997, 1998) as well as the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee (RTOC 1998) were consulted. Due to very fragmentary data, available data points from the mid-1990s were used to estimate the attribution. CFC-11 was used primarily for foam blowing, but also as a refrigerant in centrifugal chillers. CFC-12 was predominantly used for RAC, but also as a blowing agent for extruded polystyrene (XPS) foam. Since XPS foam was not common in Article 5[6] (A5) countries, no CFC-12 is attributed to foam in developing countries. Anecdotal evidence suggests flushing of RAC systems with CFCs may have been a common practice up to the late 1990s, especially in A5 countries. Therefore, an extra 10% is added to the 'other' category for those countries to account for the instant emission of CFCs during flushing.

The HCFC attribution is based on an analysis of the HCFC Phase-out Management Plans (HPMPs) of the 20 largest countries as presented in the Annex. The remaining countries are estimated based on the information that their RAC use of ODS is for servicing only.

The attribution to sectors was necessary to account for sector-specific patterns of bank accumulation. The resulting sector distribution of ODS consumption is shown in Table 1.

Table 1: Assumptions for the sector distribution of consumed ODS

	Non-A5 countries			A5 countries		
	RAC	Foam	Other	RAC	Foam	Other
CFC-11	5%	80%	15%	5%	70%	25%
CFC-12	75%	10%	15%	75%	0%	25%
	Non-A5 countries			A5 countries other than the 20 largest consumers*		
HCFC-22	70%	20%	10%	90%		10%
HCFC-141b	10%	80%	10%	90%		10%
HCFC-142b		90%	10%		90%	10%

* for large A5 countries, HPMPs were analysed for the sector distribution; data is provided in annex 1

5 Article 1 of the Montreal Protocol: 'Consumption' means production plus imports minus exports of controlled substances.

6 Article 5 countries and non-Article 5 countries as defined in Article 5 of Montreal Protocol: 'Any Party that is a developing country and whose annual calculated level of consumption of the controlled substances in Annex A is less than 0.3 kilograms per capita on the date of the entry into force of the Protocol for it [...]'

To derive the existing ODS bank from consumption data, it is also important to consider transboundary trade of equipment that contains ODS ('pre-charged'), such as domestic refrigerators and freezers (refrigerant and blowing agent) or small AC units (refrigerant). In the context of the Montreal Protocol, consumption for such mass-produced, pre-charged equipment is accounted for in the country where the equipment is produced. However, for the calculation of banks, the consumption needs to be attributed to the country where the equipment is used.

The UN COMTRADE database was utilised to extract import and export figures of pre-charged RAC equipment. This database uses the harmonised system (HS) code, which allows conclusions to be drawn regarding the corresponding RAC equipment (Table 2). The HS code version from 1988/92 was used to ensure that data series are consistent during the study period from 1990–2014.

Table 2: HS codes used by customs and corresponding RAC equipment

Version	Code	Official text
HS 1988/92	841510	Air conditioning machines: window or wall types, self-contained or 'split system'
HS 1988/92	841581	Air conditioning machines: incorporating a refrigerating unit and a valve for reversal of the cooling/heat cycle (reversible heat pumps)
HS 1988/92	841582	Air conditioning machines: incorporating a refrigerating unit
HS 1988/92	841810	Combined refrigerator-freezers, fitted with separate external doors
HS 1988/92	841821	Refrigerators, household type, compression-type
HS 1988/92	841829	Refrigerators, household type, other
HS 1988/92	841830	Freezers of the chest type, not exceeding 800 l capacity
HS 1988/92	841840	Freezers of the upright type, not exceeding 900 l capacity
HS 1988/92	841850	Other refrigerating or freezing chests, cabinets display counters, show-cases and similar refrigerating or freezing furniture
HS 1988/92	841861	Other refrigerating or freezing equipment; heat pumps: compression type units whose condensers are heat exchangers
HS 1988/92	841869	Other refrigerating or freezing equipment; heat pumps: other

Table 3: Assumption of ODS content in pre-charged equipment

	Refrigerant	Blowing agent
Air-conditioners	Charge per Item: 1.2 kg (US EPA 2011)	
	Assumed gradual replacement of HCFC-22 by non-ODS[7]: ‹ 2000: 100% HCFC-22 2005: 90% HCFC-22 2010: 70% HCFC-22 2015: 50% HCFC-22 › 2017: 0% HCFC-22	
Fridges	Charge per Item: 0.32 kg refrigerant[8]	Charge per Item: 0.87 kg blowing agent[9]
	Assumed gradual replacement of CFC-12 by non-ODS: ‹ 1995: 100% CFC-12 › 2004: 0% CFC-12	Assumed gradual replacement of CFC-11 by HCFC-141b and non-ODS: ‹ 1995: 100% CFC-11 2000: 50% HCFC-141b, 50% non-ODS › 2014: 0% non-ODS

Additional assumptions were made for the initial refrigerant charge and the blowing agent content of this equipment (Table 3).

ODS flow from transboundary trade of pre-charged equipment is only a small portion of the total consumption. Due to fragmentary data, the global net trade flow of ODS in pre-charged equipment is negative. This is because more equipment is reported as exported than imported.

Consequently, the data from transboundary trade was corrected for the five most-widely used substances and for each of the foam and RAC uses for the time series between 1990 and 2014.

To increase the match of emission patterns, the RAC and the foam sectors are treated separately.

7 Assumptions are based on qualitative analysis of current HPMPs regarding the transition of AC manufacture of pre-charged ACs to HFCs and other alternatives.

8 To account for different fridge sizes, the average of the European WEEE Forum Standard (0.128 kg) and an average given by the US EPA (0.51 kg) was used (Sources: WEEE 2007, US EPA 2011).

6.2 Calculation of ODS banks in the refrigeration and air conditioning sector

The calculation is based on the methodology in the IPCC Good Practice Guidelines 2006 for Tier 1a (equation 7.2A)[9]. The formula follows the logic that all chemicals that are not emitted will build up the banks. The ODS contained in products and equipment in use[10] is the most important part of the bank in the RAC sector (apart from others such as bulk stocks).

The ODS bank is defined as ‘reachable’ if the ODS can be recovered when products and equipment enter the waste stream at their decommissioning. Equipment and products that end up landfilled or are left or treated at illegal sites are considered ‘lost’ and are therefore not included in the reachable bank.

9 IPCC 2006, Chapter 7, page 7.14

10 Although bank is referred to as ‘ODS contained in equipment in use’, the approach does not look at equipment numbers to calculate banks.

$$Bank_y = Consumption_y * (1 - EF_{fy}) + Bank_{y-1} * (1 - EF_{bank}) - EOL_y$$

$$EOL_y = Consumption_{y-LT} * R_{IC}$$

WHERE

y	year
LT	Lifetime of equipment containing the refrigerant
EF_{fy}	Emission factor in the first year, accounting for transport losses, container heels, etc.
EF_{bank}	Emission factor of the bank, accounting for refrigerant leakages during use
EOL	Refrigerant contained in equipment that is taken out of use (decommissioned)
R_{IC}	Percentage of consumption that is used for the first fill of equipment (in contrast to topping up during servicing)

The emission factors are different for developed and developing countries, accounting for varying standards in refrigerant handling and recycling procedures. Values are based on IPCC Tier 1 a/b approach and provided in Table 4.

Table 4: Assumptions for bank estimate in the RAC sector (Approach Tier 1 a/b, weighted average of sub-applications listed in Table 7.9

	IPCCs default values	Developed C.	Developing C.
EF_{fy}	0.2–3%	2%	10%
EF_{bank}	15%	15%	20%
EOL	15	15	20
R_{IC}	1/3	1/3	1/3

The refrigerant contained in equipment reaching decommissioning is estimated by applying a percentage to the consumption (R_{IC}). This percentage is assumed to be 1/3 of the consumption[11]. This amount of ODS is assumed to be available for recovery, reclamation or destruction.

A limitation of the model is the divergence between calculated bank development and the calculation of refrigerant reaching decommissioning when the majority of bank accumulation took place before the available data series (before 1990) and refrigerants are phased-out. Because of the low annual addition resulting from the phase-out schedule, the bank disappears faster than the calculated decommissioned refrigerant. This is based on the consumption when the now decommissioned equipment entered the market. To avoid decommissioned refrigerant from a non-existing bank, those values where set to zero.

11 IPCC 2006, Chapter 7, page 7.45: 'In a mature market, two thirds of the sales of a refrigerant are used for servicing and one third is used to charge new equipment.' In a premature market, a larger portion of the sales are used for the charge of new equipment, whereas during transition to substitute refrigerants, the portion used for charging new equipment will decline. Nevertheless, as an average, the given ratio is used to estimate the amount of refrigerant contained in the fleet of equipment in a single year.

6.3 Calculation of ODS banks in the foam sector

The formula for the calculation of bank in the foam sector is based on assumptions for closed-cell foam laid out by Gamlen in the IPCC Guidelines 2006 in Table 7.5[12].

The same logic applies as in the RAC sector: all chemicals that are not emitted are part of the bank.

Only ODS foams from equipment or building materials that enter the waste stream at end of life are considered as a 'reachable' bank. Unwanted materials and equipment that end up landfilled or are illegally disposed are considered 'lost' and are therefore not included in the reachable bank.

$$Bank_y = Consumption_y * (1 - EF_{fy}) + Bank_{y-1} * (1 - EF_{bank}) - EOL_y$$

$$EOL_y = Consumption_{y-LT} * (1 - EF_{fy} - EF_{bank} * LT)$$

WHERE

y	year
LT	Lifetime of equipment containing the refrigerant
EF_{fy}	Emission factor in the first year, accounting for transport losses, container heels, etc.
EF_{bank}	Emission factor of the bank, accounting for refrigerant leakages during use
EOL	Refrigerant contained in equipment that is taken out of use (decommissioned)

The deduction of blowing agent contained in equipment at decommissioning is determined based on an adapted Gamlen model. Originally, Gamlen (1986) states that the emission patterns of closed-cell foam are the least well-defined. The emission factors given as the IPCC default values aim at a conservative (meaning high) emission rate. This is justified for guiding the calculation of emissions. However, this exercise aims at estimating what is not emitted and thus proposes emission factors that do not lead to the (near) total loss of blowing agent over the lifetime. The choice of emission factors also takes into account the broad variation of emission patters of different foam sub-applications, ranging from 100% loss of blowing agent in the first year to more than 92% of the blowing agents still being present at decommissioning[13]. Emission factors are different for developed and developing countries, accounting for varying standards in blowing agent handling and foam production. Values are provided in Table 5.

Table 5: Assumptions for foam sector bank calculation

	Default values (Gamlen)	Developed countries	Developing countries
EF_{fy}	5-10%	5%	10%
EF_{bank}	4.5%	2%	2%
Lifetime	20	20	20
Blowing agent left at EOL (% of Initial Charge)	0-5%	55%	50%

12 IPCC 2006, Chapter 7, page 7.35

13 IPCC 2006, Chapter 7, page 7.37, tables 7.6 and 7.7

6.4 Substance use extracted from HPMPs of 20 Article 5 countries with highest consumption

Country	Substance	Data year	RAC use	Foam use	Other use
Argentina	HCFC-141b	2010	12%	83%	5%
	HCFC-142b	2010	87%	12%	1%
	HCFC-22	2010	96%	0%	4%
Bangladesh	HCFC-141b	2010	0%	100%	0%
	HCFC-142b	2010	100%	0%	0%
	HCFC-22	2010	100%	0%	0%
Brazil	HCFC-141b	2009	0%	95%	5%
	HCFC-142b	2009	0%	100%	0%
	HCFC-22	2009	100%	0%	0%
China	HCFC-141b	2013	0%	92%	8%
	HCFC-142b	2013	12%	88%	0%
	HCFC-22	2013	85%	15%	0%
Cote d'Ivoire	HCFC-22	2010	100%	0%	0%
Democratic People's Republic of Korea	HCFC-141b	2013	0%	100%	0%
	HCFC-22	2013	100%	0%	0%
Egypt	HCFC-141b	2010	0%	100%	0%
	HCFC-22	2010	99%	1%	0%
India	HCFC-141b	2010	12%	83%	5%
	HCFC-142b	2010	87%	12%	1%
	HCFC-22	2010	96%	0%	4%
Indonesia	HCFC-141b	2009	35%	65%	0%
	HCFC-22	2009	100%	0%	0%
Iran (Islamic Republic of)	HCFC-141b	2011	45%	55%	0%
	HCFC-22	2011	99%	1%	0%
Iraq	HCFC-124	2010	100%	0%	0%
	HCFC-142b	2010	100%	0%	0%
	HCFC-22	2010	100%	0%	0%
Kuwait	HCFC-141b	2012	0%	100%	0%
	HCFC-142b	2012	0%	100%	0%
	HCFC-22	2012	85%	15%	0%
Malaysia	HCFC-141b	2009	0%	100%	0%
	HCFC-22	2009	100%	0%	0%

Country	Substance	Data year	RAC use	Foam use	Other use
Mexico	HCFC-141b	2010	35%	60%	5%
	HCFC-142b	2010	0%	100%	0%
	HCFC-22	2010	87%	7%	6%
Nigeria	HCFC-141b	2010	60%	40%	0%
	HCFC-22	2010	100%	0%	0%
Pakistan	HCFC 141b	2009	0%	100%	0%
	HCFC-22	2009	100%	0%	0%
Paraguay	HCFC-141b	2009	0%	100%	0%
	HCFC-142b	2009	100%	0%	0%
	HCFC-22	2009	100%	0%	0%
Philippines	HCFC-141b	2011	31%	69%	0%
	HCFC-22	2011	100%	0%	0%
Saudi Arabia	HCFC-141b	2010	5%	95%	0%
	HCFC-142b	2010	0%	100%	0%
	HCFC-22	2010	93%	7%	0%
Senegal	HCFC-22	2009	100%	0%	0%
South Africa	HCFC-141b	2010	0%	98%	2%
	HCFC-142b	2010	100%	0%	0%
	HCFC-22	2010	97%	3%	0%
Thailand	HCFC-141b	2010	0%	90%	10%
	HCFC-22	2010	100%	0%	0%
Venezuela (Bolivarian Republic of)	HCFC-141b	2009	0%	100%	0%
	HCFC-142b	2009	100%	0%	0%
	HCFC-22	2009	100%	0%	0%
Viet Nam	HCFC-141b	2012	0%	100%	0%
	HCFC-22	2012	100%	0%	0%

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