Proklima

Management and destruction of existing ozone depleting substances banks

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The Montreal Protocol on substances that deplete the ozone layer (ODS) has been effectively controlling the production and consumption of ODS since 1989. However, large banks of ODS accumulated globally by the excessive historical use of these substances, which are continuously released from the banks to the atmosphere and damaging the ozone layer and global climate. These banks are not controlled by the Montreal Protocol. Adequate collection, recovery and destruction of ODS banks is a real challenge for developing countries. We review the status quo of ODS bank management in developing countries, highlight barriers and discuss promising policy measures. We want to provide useful information to improve ODS bank management, particularly in developing countries to protect the ozone layer and to limit global warming.

The International Climate Initiative

Since 2008, the International Climate Initiative (IKI) of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) has been financing climate and biodiversity projects in developing and newly industrialising countries, as well as in countries in transition. Based on a decision taken by the German parliament (Bundestag), a sum of at least 120 million euros is available for use by the initiative annually. For the first few years the IKI was financed through the auctioning of emission allowances, but it is now funded from the budget of the BMUB. The IKI is a key element of Germany's climate financing and the funding commitments in the framework of the Convention on Biological Diversity. The Initiative places clear emphasis on climate change mitigation, adaption to the impacts of climate change and the protection of biological diversity. These efforts provide various co-benefits, particularly the improvement of living conditions in partner countries.

The IKI focuses on four areas: mitigating greenhouse gas emissions, adapting to the impacts of climate change, conserving natural carbon sinks with a focus on reducing emissions from deforestation and forest degradation (REDD+), as well as conserving biological diversity.

New projects are primarily selected through a two-stage procedure that takes place once a year. Priority is given to activities that support creating an international climate protection architecture, to transparency, and to innovative and transferable solutions that have an impact beyond the individual project. The IKI cooperates closely with partner countries and supports consensus building for a comprehensive international climate agreement and the implementation of the Convention on Biological Diversity. Moreover, it is the goal of the IKI to create as many synergies as possible between climate protection and biodiversity conservation.

GIZ Proklima

Proklima is a programme of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Since 2008 Proklima has been working successfully on behalf of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) under its International Climate Initiative (IKI) to disseminate ozone-and climate-friendly technologies.

Proklima has been providing technical and financial support for developing countries since 1996, commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) to implement the provisions of the Montreal Protocol on Substances that Deplete the Ozone Layer.

Contents

Abbreviations

AC	Air conditioning
ADF	Advanced Disposal Fees
BAT	Best-available technologies
BAU	Business as usual
BMUB	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
BMZ	German Federal Ministry for Economic Cooperation and Development
CAR	Climate Action Reserve
CAT	Climate Action Tracker
CCX	Chicago Climate Exchange
CDM	Clean Development Mechanism
CFC	Chlorofluorocarbon
CTOC	Chemicals Technical Options Committee
DIN	German industry norm
DP	Densely populated
DRE	Destruction and removal efficiency
DSD	Duales System Deutschland
EC	European Commission
ECA	Europe and Central Asia
ELV	End-of-life vehicle
EOL	End of life
EPR	Extended Producer Responsibility
EU ETS	European Union Emissions Trading System
EUA	European Union Allowance
GEF	Global Environment Facility
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GWP	Global warming potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HPMP	Hydrochlorofluorocarbon Phase Out Management Plans
HTOC	Halons Technical Options Committee
IKI	International Climate Initiative
IMPEL	European Network for the Implementation and Enforcement of Environmental Law
IPCC	International Panel on Climate Change
ISWA	International Solid Waste Association
JI	Joint implementation
LVC	Low volume country
MEPS	Minimum energy performance standards
MLF	Multilateral Fund for the Implementation of the Montreal Protocol
MP	Montreal Protocol
NAMA	National appropriate mitigation actions
ODP	Ozone depletion potential
ODS	Ozone depleting substances
OECD	Organization for Economic Co-operation and Development
PIC	Prior informed Consent procedure
PCB	Polychlorinated biphenyl
POP	Persistent Organic Pollutant
PRO	Producer Responsibilities Organisation
RAC	Refrigeration and air-conditioning (sector)
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RGGI	Regional Greenhouse Gas Initiative
SLCF	Short-lived climate forcers
SP	Sparsely populated
TBM	Transboundary movements
TEAP	Technology and Economic Assessment Panel
UCTS	Upstream combination tax/subsidy
UV	Ultraviolet
VCS	Voluntary Carbon Standard
WEEE	Waste Electrical and Electronic Equipment
XPS	Extruded polystyrene

Executive Summary

This study analyses the management and destruction of ozone depleting substances (ODS), particularly in developing countries. ODS are primarily used as refrigerants, foam blowing agents, but also in fire-fighting equipment and other applications. This study reviews the status quo of ODS bank management, provides an overview of global ODS banks, relevant legislation, technical options for ODS destruction as well as financing and policy mechanisms. It also looks at the different barriers that hinder effective ODS management and destruction.

Even though the consumption and production of ODS has been effectively controlled by the Montreal Protocol on Substances that Deplete the Ozone Layer, accumulated ODS banks in old refrigeration and air conditioning appliances but also in insulation foams and fire-fighting equipment still reach the atmosphere to a large extent. Their management and destruction could not only accelerate the recovery of the ozone layer but also protect the climate as ODS generally have very high global warming potentials. Whilst ODS bank management was never the subject of an international agreement, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal has to be observed when ODS are transported to another country for destruction or reclaim. The Basel Convention is the most comprehensive agreement on hazardous waste with the primary aim of protecting human health and the environment.

Halons have the highest ozone depletion potential, but are not further considered in this study as their destruction is specifically not recommended and halons appear as sufficiently managed.

The study gives a comprehensive data set on existing ODS banks, drawing information from all studies published about the topic. Banks are defined as “total amount of substances contained in existing equipment, chemical stockpiles, foams and other products not yet released to the atmosphere”. The total estimate of reachable ODS banks, i.e. banks available for management, is 5,354 kt. This corresponds to 3,037 kt ODP and 16.8 Gt CO2eq. Numbers are given aggregated for A2 and A5 countries as country-specific data are only available for very few countries. At the moment less than 50 % of the reachable banks are in developing countries but the amount of manageable ODS in banks will gradually shift from developed countries to developing countries over the next few years.

Not all reachable banks can be recovered at a reasonable level of effort and cost, which is defined as the technical feasibility. The technical feasibility of ODS from all refrigeration and air conditioning subsectors can be collected with low or medium effort. Different foam types (e.g. insulation, construction) however, are more difficult to process and are categorised as medium to high level (partly technically unproven).

Destruction technologies can be categorised in high temperature incineration, plasma technologies, and other non-incineration technologies. There are currently sixteen TEAP approved technologies for the destruction of ODS. Costs related to recovery and destruction vary significantly between subsectors and range between less than 10 (commercial refrigeration) to over 100 (steel faced foam panels) US$ per kg ODS.

ODS management and destruction activities are hindered by many different factors. The following barriers have been identified based on an analysis of existing project proposals and project experiences: Informational (e.g. lack of knowledge about environmental hazards of ODS/ODS amounts in country), financial (e.g. missing funding for collection, destruction technology, operation), technical (e.g. problems with or lack of technical equipment), logistical (e.g. informal waste collection sector, geographic distribution of waste) and legal (e.g. lack of ODS venting ban,

export for destruction hindered by Basel Convention). Many barriers relate to establishing the right policy framework for successful ODS management projects. Others however, emerge from the chosen policy and financing mechanism.

Appropriate policy measures are necessary for a successful ODS bank management and to overcome the mentioned barriers. The following key measures have been identified: Regulations, such as banning the venting of ODS, mandatory recovery of ODS during servicing and mandatory recovery of ODS at the end-of-life of equipment. Putting in place structures to enforce existing regulations is of high importance. Regulations should also include stipulations about technician training and certification, as this is a necessary part of ODS management.

Two financing mechanisms are analysed in detail: Extended Producer Responsibility (EPR) and the Voluntary Carbon Market (VCM). EPR schemes shift the financial responsibility from municipalities to producers. It is therefore an incentive for the production of environmental sound products. The VCM as a financing mechanism for ODS destruction should be viewed critically. It could not only give a perverse incentive of increasing ODS production for destruction but also encourage CO_2 emissions that can be offset by ODS destruction credits.

The engagement of ODS bank management in developing countries varies significantly. Several developing countries have established a halon bank management system, and have demonstration projects for ODS destruction (mainly for CFC), co-funded by the Multilateral Fund. In total, the MLF approved approx. 12 million US$ for 14 demonstration projects over the last 5 years. The chances for a successful ODS bank management are increased under certain pre-conditions, such as advanced activities in the (electrical) waste sector and ambitious national climate goals.

1 Introduction

The Montreal Protocol has been effectively restricting the production and consumption of ozone depleting substances (ODS). Because of the concerted actions under this Protocol since 1989, the ozone layer has not deteriorated further since 2000 and is believed to start recovering (SAP 2014). Not only because of these results, is the Montreal Protocol considered as one of the most successful international environmental agreements.

However, large banks accumulated globally by the excessive historical use of ODS, because the Montreal Protocol and any other international environmental convention do not regulate the management and destruction of ODS, which are for example found in old refrigeration and air conditioning appliances but also in insulation, building and other foams. These will therefore be released to the atmosphere over the coming decades if no further action is taken (SAP 2014) with strong negative environmental impacts not only for the ozone layer.

ODS, such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), and other synthetic greenhouse gases, such as hydrofluorocarbons (HFCs), are potent greenhouse gases with high global warming potential (GWP). Therefore, a reduction of ODS emissions could not only protect the ozone layer but considerably contribute to mitigate climate change.

The latest IPCC report (IPCC2013) has again confirmed the urgency to reduce greenhouse gas emissions in order to prevent temperatures to rise more than 2°C by the end of the century. A reduction of CO_2eq of 40-70% compared to 2010 by 2050 and near-zero emissions by 2100 are necessary to restrict global warming to this extent, which would keep negative impacts to a minimum.

Managing and destroying ODS banks is urgent as the next 35 years are critical for both the climate and limiting the negative effects of ozone layer depletion (SAP 2014, IPCC 2013). The next few years offer a small window in time where ozone layer recovery can be accelerated by several years and fast action on climate change could be achieved with relatively little effort. However, there are many barriers to ODS management and destruction, especially in developing countries.

This study analyses existing literature and draws from experiences gathered in previous projects in order to answer the following key questions for conducting successful ODS bank management and destruction projects.

- Which volume of ODS banks is reachable for destruction, today and in future?
- What is the geographical distribution of existing ODS banks?
- Which sectors and which substances are most important regarding emission reduction?
- What are the destruction methods and technologies for ODS bank disposal and which of these are technically and economically feasible?
- What are the main barriers for ODS bank destruction?
- What are sustainable policy and financing options for managing ODS banks?

1.1 Ozone depleting substances and their environmental impact

The ozone layer in the stratosphere protects the earth from UVB radiation. Its relatively short wavelength means that it is higher in energy and can therefore be harmful for human beings, terrestrial and aquatic organisms and ecosystems (SAP 2002). Ozone depleting substances contain chlorine or bromine ions that cause chemical reactions in the stratosphere leading to the depletion of ozone. The ozone depletion potential (ODP) stands for the relative ability of a substance to deplete stratospheric ozone and is measured relative to CFC-11, which has been given an ODP of 1. ODPs of CFCs range from 0.26 to 1.0 (Table 1). HCFCs have lower chlorine content and therefore lower ODPs in the range of 0.02 to 0.102. Halons have the highest ODPs (6.7-15.9). ODPs are still subject to scientific research and are updated regularly, such as in the recent SAP study (SAP 2014) (see Table 1). However, for official phase-down calculations, the original data from the Montreal Protocol are used. ODP tonnes[1] allow comparing the potential of different ODS to destroy ozone.

Most ODS also have very high GWP: CFCs have the highest GWP, ranging from around 5,000 to over 10,300 (Table 1). GWPs of HCFCs are lower, between 300 and 5,000. Ozone depletion in the stratosphere results in negative radiative forcing and therefore cooling in the troposphere, thereby reducing the GWP of ODS. For CFCs and HCFCs the negative indirect effects seem high, but the resulting GWPs are still highly significant for global warming. For halons on the other hand, the indirect GWP is in the range of several tens of thousands; this is more than compensating for the direct GWP (SAP 2014).

Table 1: Characteristics of some relevant CFCs, halons, HCFCs and other halocarbons. Lifetimes, ODP as stated in the Montreal Protocol and SAP (2014) as well as GWP and indirect GWP from ozone depletion (SAP 2014) are given.

	Lifetime (years ± uncertainty)	**ODP (Montreal Protocol**	**ODP (SAP 2014)**	**GWP (100 year basis)**	**Indirect GWP from ozone depletion**
CFCs					
CFC-11	52 ± 22%	1.0	1.0	5160	-2640
CFC-12	102 ± 15%	1.0	0.73	10300	-2100
CFC-113	93 ± 17%	0.8	0.81	6080	-2150
CFC-114	189 ± 12%	1.0	0.5	8580	-914
CFC-115	540 ± 17%	0.6	0.26	7310	-223
Halons					
halon-1301	72 ± 13%	10.0	15.2	6670	-44,500
halon-1211	16 ± 29%	3.0	6.9	1750	-19,000
halon-2402	28 ± 19%	6.0	15.7	2030	-32,000
HCFCs					
HCFC-22	12 ± 16%	0.055	0.034	1780	-98
HCFC-123	1.3 (WMO, 2011)	0.02			-37
HCFC-124	5.9 (WMO, 2011)	0.022			-46
HCFC-141b	9.4 ± 15%	0.11	0.102	800	-261
HCFC-142b	18 ± 14%	0.065	0.057	2070	-152
HCFC-225ca	1.9 (WMO, 2011)	0.025			-40

[1]Calculated by multiplying the mass of a substance with the specific ODP.

	Lifetime (years ± uncertainty)	ODP (Montreal Protocol	ODP (SAP 2014)	GWP (100 year basis)	Indirect GWP from ozone depletion
HCFC-225cb	5.9 (WMO, 2011)	0.033			-60
Other halocarbons					
CH_3Br	0.8 ± 17%	0.6	0.57		-1250
CH_3CCl_3	5.0 ± 3%	0.1	0.14	153	-319
CCl_4	26 ± 17%	1.1	0.72	1730	-2110

It is now estimated that ODP weighted emissions from banks are higher than those from future ODS production (SAP, 2014). This is due to future ODS production being limited to HCFCs with lower ODPs. By destroying these banks, 1.8 million ODP-tonnes could be avoided until 2050 (SAP 2014). Of these, approximately 0.85 ODP-tonnes can be attributed to CFC and halon banks each. About 0.1 ODP-tonnes are due to HCFC banks. Their destruction could accelerate the recovery of the ozone layer by 6.5 years.

The GWP weighted emissions from future production of ODS equal those from banks (SAP 2014). Emissions from CFC, HCFC and halon banks amount to 10 Gt CO_2eq that will be released by 2050 if no further action is taken. The contributions of CFCs and HCFCs are thereby comparable, whilst that of the halon bank is negligible. The radiative forcing due to ODS has stabilised over the last years and a decrease is expected with further compliance with the Montreal Protocol (SAP 2014).

It is estimated that by 2050, banks of HFC will be as high as 65 Gt CO_2eq as they are often used in products with long lifetimes. Their effect on the climate could be reduced significantly by limiting future uses or destroying banks (SAP 2014).

1.2 Management and destruction of ozone depleting substances

In order to conduct successful ODS management with the aim of environmentally friendly destruction, it is not sufficient to only install destruction technology. The following five elements are necessary (Figure 1):

- National **legislation** has to be in place that requires the collection and/or destruction of ODS, bans ODS venting, and puts in place proper procedures for servicing and end-of-life recovery of ODS containing equipment (e.g. through extended producer responsibility schemes). **Regulations** about how the laws will be enforced are necessary and **enforcement** has to be secured.
- **Organisation** and **management** of ODS management and destruction have to be in the responsibility of qualified state bodies such as environmental protection agencies or national ozone offices. It is crucial to consider **quality assurance** where ODS banks from inventories are linked to destruction certificates in order to confirm their destruction. Another important point is the adequate training and certification of involved personnel.
- A **financing mechanism** for the management of ODS as well as destruction technologies and assuring long-term sustainability of destruction activities are necessary.
- A **collection system** for ODS wastes and a **logistic** concept have to be established. These depend on the targeted ODS containing sectors (e.g. household applications such as refrigerators and air-conditioners or insulation foams), already existing waste collection infrastructure within the country and geographical conditions.

- **Recycling** or **destruction technology** adequate for expected ODS waste streams has to be made available in the country. If this is not the case, the possibility to export ODS waste has to be given.

Figure 1: Elements of successful ODS management and destruction systems.

The logistics of ODS collection and destruction comprise several steps for which infrastructure has to be established (Figure 2). Depending on the sector, appliances or gases have to be collected or collection centres have to be established where units can be handed in. Special recovery equipment is then necessary to recover refrigerant from the equipment.

Box 1: Different categories of ODS management

Recovery:	Removing refrigerant in any condition from a system and storage in an external container
Recycling:	Reduction of contamination in used refrigerants with the aim of the subsequent reutilisation of the refrigerant
Reclamation:	Processing recovered refrigerants to new product specifications (in Germany DIN standard 8960) and verifying that new product specifications have been met by analysing the refrigerant

In order to determine whether ODS can be recycled, reclaimed (mainly refrigerants) or destroyed, testing of recovered ODS is conducted. Recovered ODS should not be stored over several years, before further treatment is taking place, because leakage rates of cylinders are given with > 10% (UNEP/Excom 2013).

Destruction is the only way to prevent ODS from reaching the atmosphere if they cannot be used anymore (e.g. because of impurities, lack of application possibilities/bans). Between all these steps, ODS or equipment containing ODS have to be transported or stored. Special requirements regarding safety should be considered for both transport and storage.

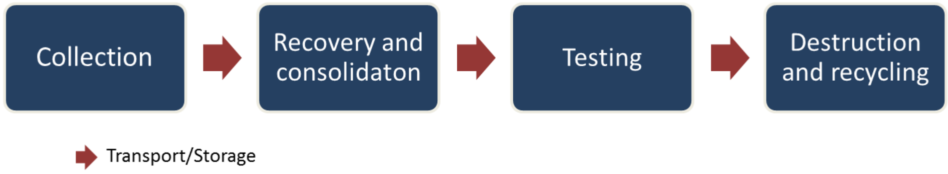

Figure 2: From collection to destruction – ODS management. Adapted from ICF (2010a).

1.3 Exclusion from ODS destruction activities

The following ODS are usually not considered for destruction projects even though they have a high environmental impact. The reasons are stated below:

Halons

Halons are used as fire-fighting and explosion suppression agents and their main application is in aviation, the military and the oil and gas industry. Their production ceased in 1994 in developed countries and in 2010 in developing countries. Even though halons have very high ODPs of 3-10, the Halons Technical Committee (HTOC) recommends in their 2010 Assessment that only cross-contaminated halons should be destroyed, for the reasons explained below according to HTOC 2011.

Alternative fire-fighting or explosion suppression agents are often not yet technically or economically feasible. The risk for fires with the potential of high fatalities (e.g. in civil aviation) could increase. The long-term strategy for the phase-out of halons has always included their continued use in critical applications and early destruction could lead to the need to produce new halons. The life-time of equipment using halons can be as long as 25-30 years, making them necessary until mid-century if halons are not installed in new equipment.
The destruction of ODS is often seen as benefiting both the ozone layer and the climate because of their high GWPs. The GWP of halons however, is lower and even estimated to be around 0 when indirect effects are accounted for (Youn et al. 2009). Many halon alternatives are hydrofluorocarbons with very high GWPs, contributing further to global warming.

Destruction schemes for halons could lead to perverse incentives to produce halon for the purpose of destruction as new halons are not distinguishable from recycled halons. This phenomenon has been observed for HFC-23 within clean development mechanism (CDM) projects. Global destruction schemes are unlikely though as many countries have prohibited the destruction of halons and there is very little practical experience with halon destruction. Furthermore, it is difficult to acquire accurate data about the amount of halons still in use as the military and some of the industries using halons often do not disclose information.

Other halocarbons

Carbon tetrachloride, methyl bromide and methyl chloroform are also ODS controlled under the Montreal Protocol. However, their global phase-out has been completed in 2010 in the case of carbon tetrachloride and will be completed in 2015 in the case of methyl bromide and methyl chloroform. Because of their use as solvents, pesticide or feedstock for the production of other chemicals, there are no significant known banks of these chemicals. They are either released into the atmosphere immediately during use or transformed (IPPC/TEAP 2005). Establishing management and destruction activities for isolated cases is not financially feasible and will therefore not be further considered in this report.

CFC and HCFC are the most widely used ODS and predominately used as refrigerants and foam blowing agents. The banks of CFC and HCFC and their possible management are the focus of this study and are covered in the following chapters.

1.4 International conventions

The **Montreal Protocol on Substances that Deplete the Ozone Layer** has been effectively controlling the production and consumption of ODS since 1989. The phase-out schedule for the CFCs and HCFCs (Figure 3) shows that the production of CFCs has already stopped globally and that the phase-down of HCFCs in developing countries will start in 2015. Lifetimes of about 7 to over 30 years of equipment using CFCs and HCFCs (Schwarz et al. 2011; GIZ 2013) mean that some of this equipment is still coming to its end-of-life now or in the future, creating banks of ODS. These banks are not covered by the Montreal Protocol.

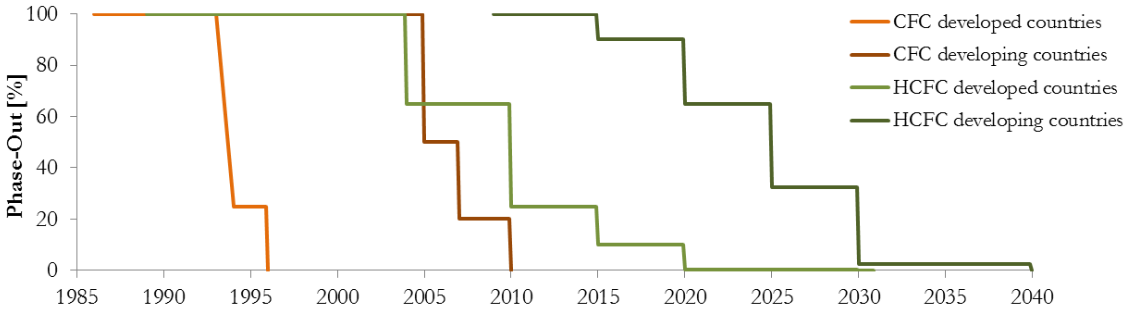

Figure 3: Phase-out schedule for CFCs and HCFCs according to the Montreal Protocol

The 4th Meeting of the Parties to the Montreal Protocol urged the Parties to take measures that prevent the release of ODS into the atmosphere, for example by recovering them for recycling, reclamation or destruction. This has been difficult to follow for developing countries and few activities regarding recycling and destruction have been undertaken (TEAP 2002b).

The Special Report on Safeguarding the Ozone Layer (IPCC/TEAP 2005) first assessed global ODS banks and led to funding being made available for demonstration projects of ODS destruction in 2008[2]. Many activities are still in the initial stage (UNEP/Excom 2013). The experience with environmentally friendly management and destruction of ODS is very limited in developing countries.
ODS were never regulated under the **Kyoto Protocol to the United Nations Framework Convention on Climate Change**. Their management and destruction has therefore never been included in CDM or joint implementation (JI)[3] projects.

The **Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal** was adopted in 1989 and entered into force in 1992 as a reaction to the frequent shipment of toxic waste from developed countries to developing countries for disposal in the 1980s (UNEP/SBC 2011a). Its primary aim was the protection of human health and the environment and it is the most comprehensive agreement on hazardous waste (UNEP/SBC 2011b). Transboundary movements (TBM) of waste are to be reduced as much as possible or, if it is

[2] 20th Meeting of the ExCom (http://www.multilateralfund.org/MeetingsandDocuments/meetingsarchive/reports/English/1/2072.pdf)
[3] http://unfccc.int/kyoto_protocol/mechanisms/joint_implementation/items/1674.php; accessed 26 January 2015.

necessary for disposal, environmentally sound management is a prerequisite. To date, 181 countries are Parties to the Basel Convention[4].

ODS are covered under the Basel Convention and are listed in Annex I of the Convention– “Categories of Waste to be controlled as Y45 – Wastes having as constituents organohalogen compounds not included under any other category”. If a country has no or no sufficient ODS destruction capacities, export is necessary and the Basel Convention has to be adhered to if it has come into force in the exporting country.

Each Party has the right to pass stricter legislation and for example completely prohibit the import of hazardous or other wastes (e.g. Colombia and Costa Rica). On the other hand, it is possible to enter into bilateral, multilateral or regional agreements to cooperate on ODS waste management and destruction. Whilst generally TBM are only allowed between Parties of the Basel Convention, it is possible when such an agreement exists and the principle of “environmentally sound management” is complied with.
There are several **examples of both stricter legislations and agreements between Parties or Parties and non-Parties**.

Whilst the USA is not a Party to the Basel Convention, a bilateral agreement with Canada allows waste to be imported for destruction.

For many developing countries, the Basel Convention did not go far enough in its restrictions as it is still possible to export waste from a developed to a less developed country. Therefore, several regional agreements were devised that only allow the import of waste from other member countries of the agreement. An overview of regional agreements is given below.

Box 2: Examples of regional agreements

The Bamako Convention on the Ban of the Import Into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa prohibits the import of hazardous wastes into Africa from non-Parties.

The Central American Agreement (Regional Agreement on the Transfrontier Movement of Hazardous Waste) prohibits import from non-party countries. It is also not possible for parties to destroy ODS from non-Parties. Members are Costa Rica, Honduras, El Salvador, Nicaragua, Guatemala and Panama.

The name of the Waigani Convention to Ban the Importation into Forum Island Countries of Hazardous and Radioactive Wastes and to Control the Transboundary Movement and Management of Hazardous Wastes within the South Pacific Region (1995) is self-explicatory.

Decision C(2001)107/Final of the Organisation for Economic Co-operation and Development (OECD) regulates the international movement of wastes and dictates the amber control procedure for hazardous waste movements, which means that TBM have to be documented strictly.

The **Stockholm Convention on Persistent Organic Pollutants** bans the production of persistent organic pollutants (POP). Import and export are restricted and only allowed for environmentally sound disposal. The Stockholm Convention works closely with the Basel Convention in order to guarantee proper transport procedures. ODS are not covered under the Stockholm Convention, but the joint destruction of ODS and POP is technically feasible. Similar

[4]http://www.basel.int/Countries/StatusofRatifications/PartiesSignatories/tabid/1290/Default.aspx#a-note-1; accessed 26 November 2014).

regulations apply to the transport of both groups of substances. Pooling transport and destruction of POPs and ODS could lead to logistic and financial synergies.

1.5 Scope and study outlook

This study is part of a wider project on ODS bank management and destruction in developing countries implemented by GIZ on behalf of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety[5]. The project aims at establishing policy framework conditions to set up national ODS bank management as well as technology cooperation in selected partner countries.

This study reviews the status quo of ODS bank management in developing countries and in particular it integrates experiences from recently approved ODS destruction projects under the Multilateral Fund (MLF) for the Implementation of the Montreal Protocol. The study further includes a technical and financial analysis of ODS bank management and destruction and looks at barriers as well as political and financial mechanisms that could help overcoming these barriers. The study is based on a literature survey, experience from previous projects and an analysis of ongoing projects and project proposals.
Furthermore, the study identifies priority sectors for ODS bank management. It will discuss the advantages and disadvantages of different financing mechanisms and highlight synergies with other waste collection activities, thereby indicating the most cost-effective strategies. The study aims to contribute to provide relevant information on ODS bank management and destruction, particularly in developing countries.

Chapter 2 gives a global overview of ODS banks, specifically for developed and developing countries, according to subsectors and their environmental impacts and comparing current and predicted banks in 2050.
Chapter 3 looks at the technical feasibility and the costs of ODS bank management. Both recovery as well as destruction technologies are examined.
Chapter 4 shows barriers to ODS management and destruction based on an analysis of destruction demonstration projects and experiences with the halon bank management.
Chapter 5 highlights important policy measures to promote ODS management.
Finally, chapter 6 gives the status quo on the engagement in ODS management activities in developing countries.

[5] http://www.giz.de/expertise/downloads/giz2014-en-ODS_WEB.pdf; accessed 26 January 2015

2 Global overview of ODS banks

Banks are defined as the “total amount of substances contained in existing equipment, chemical stockpiles, foams and other products not yet released to the atmosphere” (IPCC/TEAP 2005). The following chapter explores previous work undertaken concerning the development of definitions of ODS banks as well as a summary of published data about the present size of ODS banks and projections into the future.

2.1 Previous studies and definitions

Global ODS bank estimates were first prepared for the “Special Report on Safeguarding the Ozone Layer” in the year 2005 (SROC; IPCC/TEAP 2005). This report had a focus on the climate aspects of ODS and their substitutes and therefore published ODS banks expressed as GWP weighted tonnes. TEAP complemented SROC with a supplement report (TEAP 2005), where complete data sets of ODS banks for 2002 and 2015 were published. These comprise ODS bank estimates for developed and developing countries, split in halons, CFC and HCFC and in relevant subsectors where these substances are used; the data are expressed in metric tonnes, ODP tonnes and GWP weighted tonnes. All subsequently published studies focus on refinements of the underlying model assumptions and the global bank estimates initially presented in the SROC and which are actually based on the RIEP model (Clodic&Palandre, 2004). Table 2 gives a chronological overview over published studies on ODS banks, with important definitions and contents.

Table 2: Highlights of selected studies concerning ODS bank data modelling

Author	Year	Title	Contents
IPCC, TEAP	2005	Special Report on Safeguarding the Ozone Layer and TEAP Supplement	First comprehensive data set on ODS banks, split in developed and developing countries for 2002 and 2015
TEAP	2006	Report on Expert Meeting To Assess the Extent of Current and Future Requirements for the Collection and Disposition of Non-Reusable and Unwanted ODS in Article 5 Countries	Definition of "reachable banks" and "accessibility"
TEAP Task Force on HCFC issues	2007	Emissions Reduction Benefits arising from earlier HCFC Phase-out and other Practical Measures	First global prediction of ODS banks until 2050
TEAP XX/7 Task Force	2009	Environmentally Sound Management of Banks of Ozone-Depleting Substances; Interim and Final report	Assessment of effort levels to manage ODS banks, split in substance groups (CFC and HCFC) and sectors (refrigeration, air conditioning and foam)
TEAP XX/8 Task Force	2009	Assessment of Alternatives to HCFCs and HFCs and Update of the TEAP 2005 Supplement Report Data	Update of the TEAP 2005 data, by including accelerated HCFC phase-out; calculation of ODS banks until 2020
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	First bottom-up approach for EU Member States to estimate ODS banks
SKM Enviros	2012	Further Assessment of Policy Options for the Management and Destruction of Banks of ODS and F-Gases in the EU	Refined bottom-up approach for EU Member States to estimate ODS banks, integrating a floating point of time for EOL rather than a fixed year,

			taking the annual equipment fleet out of use over several years rather than all at the same time.
SAP	2014	Scientific Assessment of Ozone Depletion: 2014	Global aggregated emissions from ODS banks (2015-2050)

The term “reachable banks” was first introduced during an expert workshop on ODS Bank management in 2006 and the definition of ODS banks was refined. This is considered as crucial, since a keypoint of the bank definition is the assumption about the ODS destination after ODS-containing equipment reached end of life (EOL). The ODS can either be vented, landfilled with the product, recovered, recycled, reclaimed or destroyed (see definitions chapter 1). If landfilled, the ODS are still part of the bank according to the initial definition from IPCC and TEAP (2005). The later introduced term “reachable bank” provided more clarity: ODS contained in landfilled products are considered un-reachable, thus are excluded from the reachable bank (TEAP 2006). Currently there are estimates on reachable ODS banks in developed and developing countries (Table 2), however, no comprehensive data exist on landfilled ODS banks.

TEAP (2006) also introduces the term “accessibility”, which gives a qualitative indication on the effort for recovering banks. The assessment of the “accessibility” was further developed by TEAP (2009a), where detailed categories were defined in view of the recovery effort considering substance groups (CFC or HCFC) and sectors (refrigeration, air conditioning and foam).

While the data for 2002 and 2015 (TEAP 2005) are given in metric tonnes, ODP tonnes and GWP-weighted tonnes, the 2010 data (TEAP 2009) are provided in metric tonnes only. Reviewing the various studies on ODS banks, inconsistency was observed with regard to the amount of ODS banks. This is probably caused by varying assumptions of the authors with respect to "reachability" of ODS and EOL practices. The TEAP study from 2009 (TEAP 2009a) is the most up-to-date and detailed study on this issue, thus these data with reachable bank estimates for the year 2010, are presented in this chapter.

2.2 Existing ODS banks

The total estimate of reachable ODS is 5,354 kt (Figure 4a).To assess the environmental impact of ODS, it is crucial to consider ODP and GWP weighted amounts. Depending on the perspective or focus (climate vs. ozone), the one or the other aspect is more interesting. In this study we present both ODP and GWP weighted amounts, besides the metric tonnes. ODP tonnes and GWP weighted tonnes are estimated in the present study by applying conversion factors, weighted between 2002 and 2015, to include the changing substance mix over time. Globally, this results in 3,037ktODP and 16.8 Gt CO_2eq (Figure 4b and c).

From the 5,345 kt ODS (metric kilo tonnes), halons contribute 2 %,CFC 36 % and HCFC 62 % (Figure 4a). The largest proportion of ODS (61 %) is found in foam, where CFC and HCFC contribute similar shares. Refrigerants represent 35 % of the total ODS bank (metric tonnes), dominated by HCFC. Considering the ODP weighted tonnes (Figure 4b), the picture completely changes: The foam sector with CFC blowing agents is the most dominant sector (>50 %), followed by the halon sector (29 %). This is caused by the high ODP value of CFC (ODP around 1) and halons (ODP ca. 6-15). HCFCs in the refrigeration and air conditioning (RAC) and foam sectors play a minor role (9 %), considering ozone depletion.

In contrast, HCFCs are becoming important when focussing on the climate effect of ODS banks (Figure 4c): The foam sector with CFC blowing agents is still the most important sector, however, the second most important sector is the RAC sector where HCFCs are used. This is due to comparatively high GPW values of HCFC. The dominating HCFC is HCFC-22 with a GWP of 1810 (IPCC 2007).Halons play a minor role only in the climate debate.

Irrespective of whether considering the ozone or climate aspect, the foam sector with its CFC blowing agents is the most dominating sector with regard to ODS banks. From an ozone-depleting perspective halons are the second most important sector, from a climate perspective it is the HCFC used in the RAC sectors. These above mentioned figures provide a global overview about ODS banks and indicate priority areas when establishing ODS bank management.

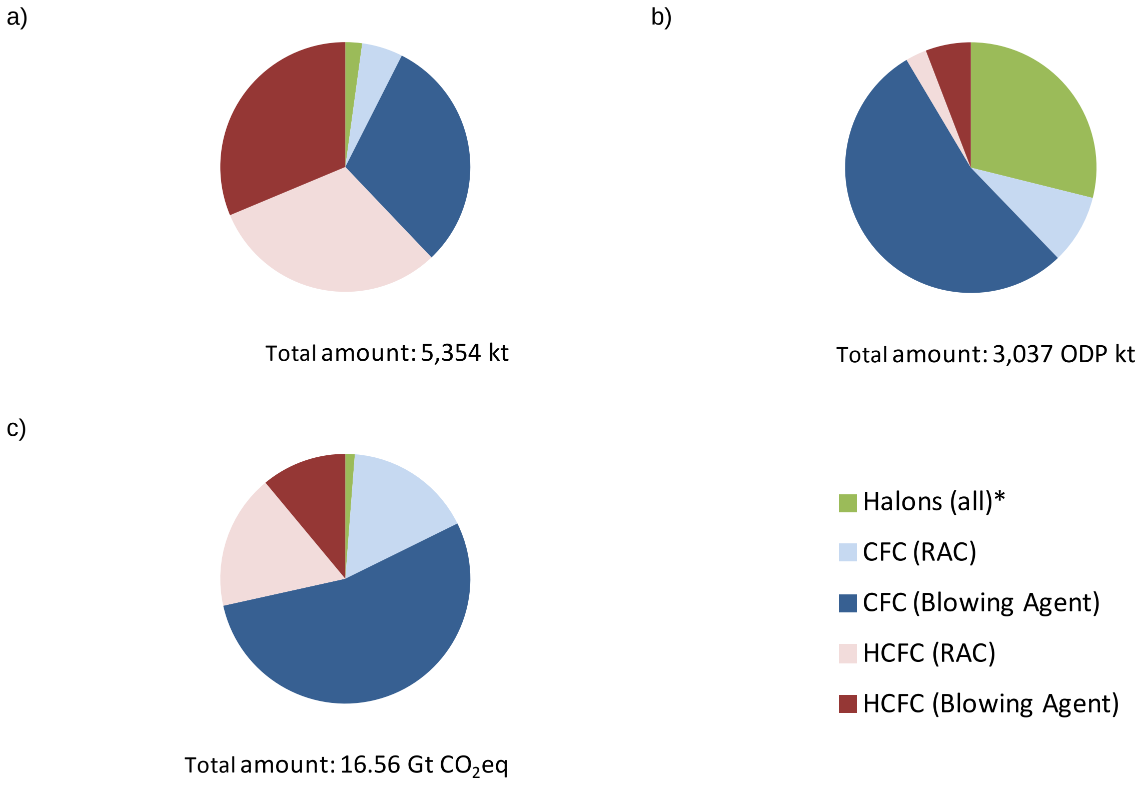

Figure 4: Projected global reachable banks 2010, given in metric tonnes (a), ODP weighted tonnes (b) and GWP weighted tonnes, modified after TEAP (2009a). "RAC" stands for refrigerants used in the refrigeration and air conditioning sector.

** sector-specific halon use is not available*

Negligible sectors are medical aerosols, non-medical aerosols, solvents and fire protection. In fire protection, predominantly halons are used. Considering metric tonnes, halons contribute to the global banks to a low extent. However, these substances have high ODP (see Figure 4b). Still, halons are not in the focus of this study and are not further considered for ODS management, because of the re-use for military purposes and in the aviation sector (HTOC 2010; see also Chapter 1). Furthermore, a halon bank management system has been established by the Montreal Protocol parties to facilitate the re-use of halons.

More than half of the global ODS bank is located in developed countries (60 % based on metric tonnes) and 40 % are located in developing countries (Figure 5). This corresponds to the differentiation of A2 and A5 countries of the Montreal Protocol. A2 countries have a per capita production and consumption of ODS greater than 0.3 kg. The ODS consumption in A5 countries is lower than this threshold and consequently, less ODS have accumulated over time.

Figure 5 shows the projected global ODS banks divided into developing and developed countries. The varying split of sectors and substances depending on considering metric tonnes, ODP or GWP weighted tonnes (Figure 5) is similar to the findings of Figure 4.

However, there are some important differences:

- In contrast to the globally aggregated data, the CFC-dominated foam sector is equally important as the halon-using sector when looking at ODP weighted tonnes (Figure 5b).
- Regarding GWP weighted tonnes; the RAC sector is the most important sector, with CFC and HCFC showing equal shares. The second most important sector is the CFC dominated foam sector.

These findings have implications for the ODS bank management in developing countries: In order to prevent emissions for the protection of both the climate and the ozone layer, the focus should be on CFC in the RAC and foam sector. As the establishment of an ODS bank management system will not be substance specific, HCFC from the RAC sector also will be covered, which is particularly important regarding GWP weighted emissions and thus the climate perspective. Within the RAC sectors, HCFCs are dominantly found in the commercial and stationary AC sector, whilst high amounts of CFC refrigerants are present in the commercial refrigeration subsector (40 % based on metric tonnes) and domestic refrigeration subsector (27 % based on metric tonnes). Within the foam sector, ca. 50 % of the CFC blowing agents are found in appliances of the domestic and commercial refrigeration subsectors.

Based on existing published data (TEAP 2009), the largest amount of ODS for recovery and destruction in developing countries will therefore be available in stationary AC (refrigerant), commercial refrigeration (refrigerant and foam) and domestic refrigeration (refrigerant and foam).

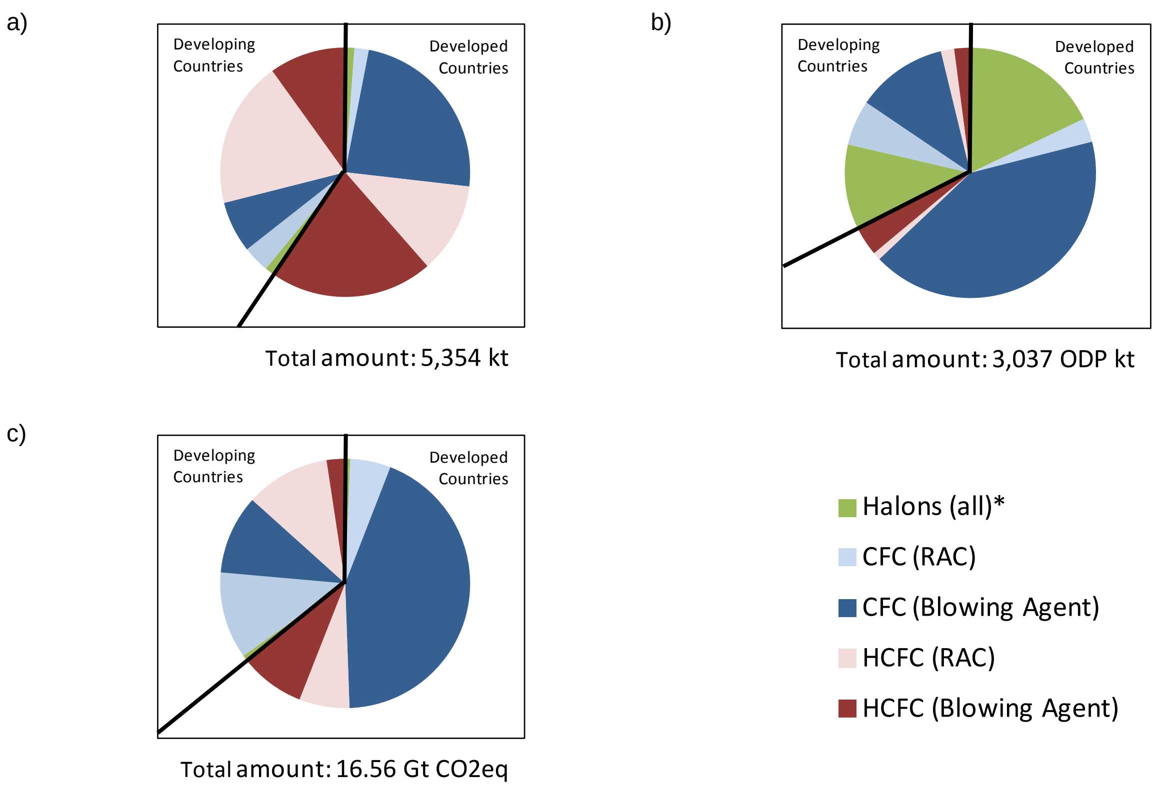

Figure 5: Projected global ODS banks (2010) in developed and developing countries, given in metric tonnes (a), ODP weighted tonnes (b) and GWP weighted tonnes (c), modified after TEAP (2009a)."RAC" stands for the refrigerants in refrigeration and air conditioning equipment.
** sector-specific halon use is not available*

In order to create future projections of the ODS banks until 2050, TEAP (2007) used the SROC data until 2015 as starting point. CFC consumption was projected along the agreed phase-out schedule and for HCFC an overall growth factor to estimate the future consumption before the phase-out was applied. The HCFC phase-out steps were interpolated to a linear trend. The annual consumption was aggregated and added to the already existing bank of the previous year. To determine emissions leaving the bank, annual emission factors for the different RAC equipment and foam types were applied where available. In case these were missing, a ratio approach was applied. The ratio between banks and emissions was determined for 2015 based on SROC data. This ratio was subsequently annually subtracted from the aggregated consumption as annual emissions. This results in a coarse bank estimate, since effects of different product lifetimes are averaged out. Thus, the projection figures do not necessarily reflected the ODS bank estimates from the year 2010 (TEAP 2009).

The projected global bank in 2050 is estimated at 2,340 kt (metric tonnes), which is less than half of the 2010 bank. The projected ODP weighted bank in 2050 is given with 1,050 ODP kt – about a third of the 2010 value. Figure 6 shows the projected bank in developed countries, Figure 7 shows the projected ODS bank in developing countries. In the projected future ODS in foam products dominate the banks of developed and developing countries because of the long product life time of construction foams used in buildings (>50 years). In developed countries, the contribution of foam, particularly CFC blowing agents, is more pronounced than in developing countries. In developed countries, the phase-out of CFC and HCFC refrigerants is completed or well advanced, meaning that the accumulation of refrigerant in banks has stopped.

In developing countries, the total bank (metric tonnes) is projected to peak between 2020 and 2030 (Figure 7a), afterwards the HCFC-refrigerant banks is expected to decline due to the HCFC phase-out schedule. Since the use of construction foam was never widely introduced in developing countries, long-lived foam products are not the main component of the bank in developing countries. Nevertheless, foam also constitutes the majority of the remaining bank in 2050 in developing countries.

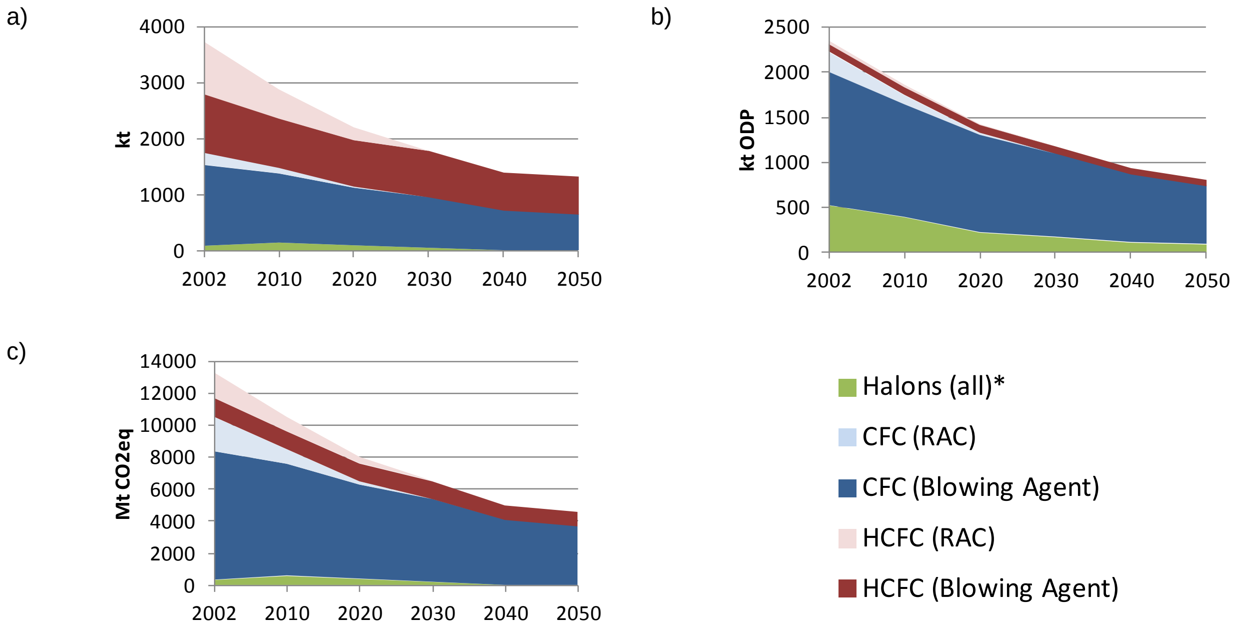

Figure 6: Projection of ODS banks in developed countries until 2050 given in metric tonnes (a), ODP weighted tonnes (b) and GWP weighted tonnes (c), modified after TEAP (2007).”RAC” stands for the refrigerants in refrigeration and air conditioning equipment.

** sector-specific halon use it not available*

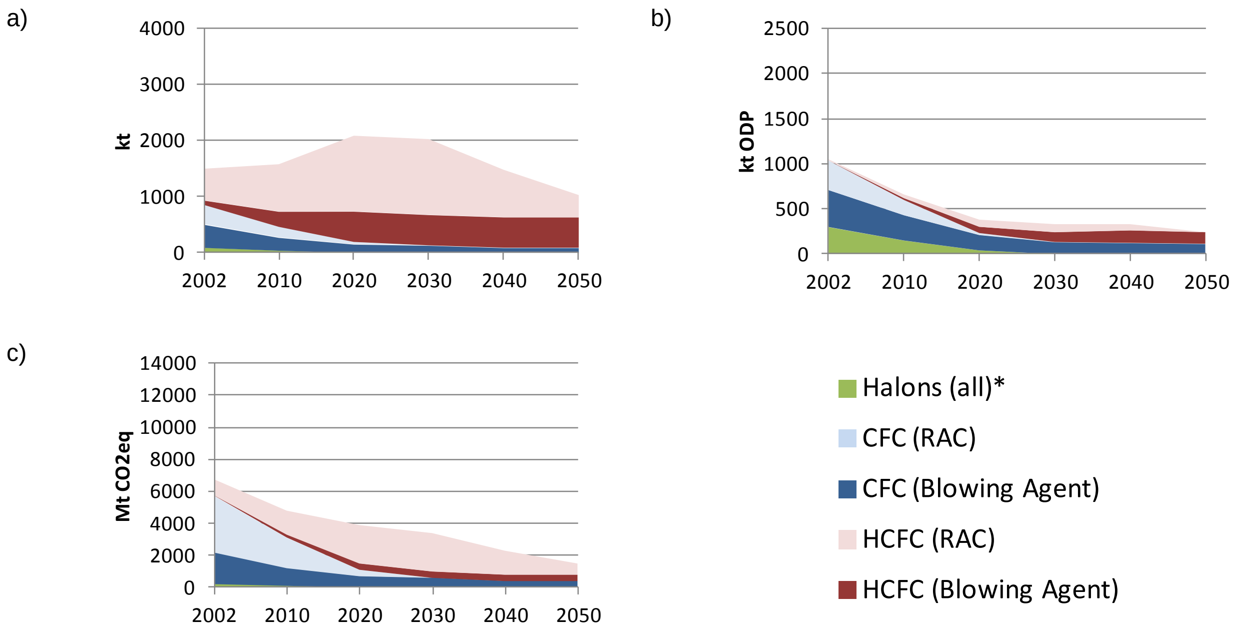

Figure 7: Projection of ozone depleting substance (ODS) banks in developing countries until 2050 given in metric tonnes (a), ODP weighted tonnes (b) and GWP weighted tonnes (c), modified after TEAP (2007).”RAC” stands for the refrigerants in refrigeration and air conditioning equipment.

** sector-specific halon use is not available*

The global ODS banks are constantly reduced mainly because ODS are vented to the atmosphere or landfilled, where products continuously lose ODS in an uncontrolled way.

The annual amount of ODS that reaches the waste stream and is therefore subject to potential ODS management is projected to peak globally in 2016 at 200 kt. The ODS amount to be managed will gradually shift from developed countries to developing countries, which might reach their peak around 2020 with 133 kt of ODS (TEAP, 2009b). The ODS reaching the waste stream in developed countries peaked already in 2010 at 90 kt.

3 Technical feasibility and costs of ODS bank management

3.1 Technical feasibility

3.1.1 ODS recovery

Technical feasibility is defined as the possibility to recover ODS at a reasonable level of effort and cost (ICF 2010). TEAP (2009a) assigned three categories of effort levels (low, medium, high) to the reachable bank in refrigeration, air conditioning and foam subsectors. Because of ongoing technical developments, these categories are only qualitatively described and avoid clear cost effectiveness boundaries. The qualitative description is based on the following three assumptions (TEAP 2006): less effort for recovery is required for

1. equipment containing larger quantities,
2. ODS that is geographically more concentrated, and
3. non-diluted ODS (e.g. refrigerant) compared to diluted ODS (such as foams).

Based on these assumptions, effort categories for recovery of ODS were assigned to RAC and foam subsectors. Even though these categories might shift over time with technology innovations, most subsectors can be tackled with low to medium effort today (Table 3). Population density also plays an important role for the effort as the parameter represents the ODS bank distribution within the country. A high urbanisation rate[6] (= densely populated area) points to aggregated banks which facilitates the establishment of collection and transport systems (TEAP 2009b) and consequently reduced costs (Table 3).

Table 3: Overview of relative effort for the recovery of reachable ODS banks at EOL. The green shading shows subsectors where banks are reachable with low to medium effort (TEAP 2009b) DP = densely populated areas, SP = sparsely populated areas

Subsector		**Effort**		
		Low	Medium	High
Domestic Refrigeration	Refrigerant	DP	SP	
	Blowing Agent	DP	SP	
Commercial Refrigeration	Refrigerant	DP	SP	
	Blowing Agent	DP	SP	
Transport Refrigeration	Refrigerant	DP/SP		
	Blowing Agent	DP/SP		
Industrial Refrigeration	Refrigerant	DP/SP		
Stationary Air Conditioning	Refrigerant	DP	SP	
Mobile Air Conditioning	Refrigerant	DP	SP	
Steel-faced Panels	Blowing Agent		DP	SP
XPS Foams	Blowing Agent			DP/SP*

[6] Population density can be assessed based on urban/rural data or urbanization rates (TEAP 2009a)

Subsector		Effort		
		Low	Medium	High
PU Boardstock	Blowing Agent			DP/SP*
PU Spray	Blowing Agent			DP*/SP*
PU Block - Pipe	Blowing Agent		DP	SP
PU Block - Slab	Blowing Agent		DP	SP
Other PU Foams	Blowing Agent			DP/SP*

* still technically unproven

ODS from all refrigeration and air conditioning subsectors can be collected with low and medium effort (green shading, Table 3). In contrast all foam types are more difficult to process, thus are categorised as medium to high level.

Low amounts of refrigerant per unit result in more specific effort per kg ODS recovered. That is, the ODS recovery from small RAC equipment, particular appliance systems, with low initial charge are more costly than larger systems. Depending on the population density and existing collection infrastructure, the effort of collecting the appliances varies considerably (Table 3). Appliances such as domestic refrigerators and freezers need to be transported carefully, as the refrigerant is only recovered at the recycling point prior to dismantling of the appliance body. Refrigerants are recovered by sucking the gas out of the refrigerant cycle. In subsectors where large amounts of refrigerants are used (industrial refrigeration), or where mobile units are found (transport refrigeration and mobile AC), population density becomes a minor issue.

Recovery rates of ODS from refrigeration systems vary depending on subsectors and handling practices. E.g. the remaining ODS content at the EOL is lower for mobile systems where leakage rates are higher, or a refrigerator that was thrown onto a truck and transported to a recovery facility on a bumpy road may have lost its refrigerant content due to a broken pipe. ICF (2010b) undertook a survey on potential recovery rates within the EU. It was stated that the remaining refrigerant content is

- 50-60% for mobile systems and industrial refrigeration plants
- 60-70% for medium to large commercial refrigeration systems and refrigerated transport
- 70-80% for large stationary chillers
- 80-90% for small commercial refrigeration and air conditioning appliances

Combined with a technically possible recovery rate of 90-95%, there is a recovery potential of 45-81% of the original refrigerant content in the EU. Actual recovery rates vary considerably between the Members States and range between 10 and 90% (ICF 2010b). For developing countries, the recovery potential are much lower due to higher leakage rates and resulting lower refrigerant amount remaining at EOL in combination with less advanced recycling and recovery techniques and less qualified technician know-how. Recovery rates are mostly below 10 % in developing countries (ICF 2010a).

Appliance foams can be treated by shredding the appliance within an airtight system that captures the foam blowing agent that is partly released during the shredding process. The shredded foam which still contains blowing agents, is separated from the metal fraction and can then be either incinerated to destroy foam and blowing agent together or the blowing agent can be separated from the foam for reclamation or destruction. This shredding process is rather energy intensive and is observed to consume up to 35 kWh per appliance (ICF 2010b), for example a domestic refrigerator. This energy amount (35 kWh) corresponds to the average energy consumption of a refrigerator per month. Thus the disposal process of appliance foam is rather cost intensive. However, the environmental impact of this high energy consumption for disposal, measured in CO_2eq, is negligible when compared to the avoided emission from blowing agent destruction[7]. Removing the foam manually after slicing the appliance, drastically reduces the energy input to about 5 kWh per appliance. However, from an environmental point of view, manual dismantling releases a substantial amount of the blowing agent into the atmosphere and cannot be recommended (Dehoust, 2010).

The challenge with foam used in the building construction is the separation and collection of foam during building renovation or demolition. Depending on the foam type and application method, this can even be done with medium effort, for example steel-faced panels. In contrast, PU spray foam is naturally adhesive to the surface it is sprayed on. Separating the foam from the surface might release the blowing agent content, therefore processing PU spray foam is presently not possible with reasonable effort. This holds true for the majority of foam types.
The effort needed for the collection of construction foam is also depending on the existing practices of segregating demolition material. In countries, where the segregation of demolition material is common practise, construction foam can be collected with lower additional effort (TEAP 2009a).

3.1.2 ODS recycling and reclaim

Recycling of ODS can be desirable and financially viable if production of the substance in question has been ceased but there is still a considerable number of equipment in the country using it. It requires a basic cleaning process, such as filtering and drying and can be done with rather simple equipment.

Reclaim is more costly and resource intensive than recycling. The Westfalen AG for example is one of just two reclaim facilities in Germany and applies the following resource intensive claim procedure according to standards[8]: Firstly, the content of delivered cylinders must be analysed with regard to chemical substances. Among others, mass spectrometer are used for this purpose, the results are summarised in an audit report. Only refrigerants with a 99 % purity is acceptable for reclaim. An impure refrigerant, which contains more than 1 % of another refrigerant will be forwarded to destruction facilities as it cannot be used for reclaim. The delivery of impure refrigerants is common in Germany, even though blending refrigerants is prohibited according to DIN EN 378-4. The reclaimed refrigerants are sold as virgin goods, the quality is defined in DIN 8960.
However, export for reclaim is also standard practice. The German supermarket chain REWE for example exports refrigerants to the UK for reclamation.

3.1.3 Destruction technologies

This chapter provides a short overview on available destruction technologies, ODS destruction requires high temperatures above 1200°C and a rigorous control of potentially forming destruction by-products, such as dioxins, acid gases or carbon monoxide.

Destruction technologies are subject to constant development and several new technologies recently entered the market. Out of them, sixteen technologies were approved to be suitable for the destruction of ODS by TEAP (2011).

[7] When applying an emission factor of 0.5 kg CO_2/kWh, the foam destruction process of a refrigerator causes ca. 18 kg CO_2eq due to the energy need. In comparison, the environmental benefits of destroying the blowing agent CFC-11 within the foam is given with 1.6 t CO_2eq. Accounting for the refrigerant (CFC-12), additional 2.2 t CO_2eq are prevented from being emitted into the atmosphere.
[8] Technical discussion: „Service und Entsorgung von Kälteanlagen“, September 2014, Umwelthilfe, Berlin

The majority of them was approved in 2002, when TEAP defined a destruction and removal efficiency (DRE) of 99,99 % for concentrated sources such as refrigerants and 95 % for non-concentrated sources such as foams along with specific minimum standards on the emission of atmospheric pollutants[9] (TEAP 2002, 2011). The approved technologies were grouped into three categories:

- high temperature incineration,
- plasma technologies, and
- other non-incineration technologies.

Incineration technologies usually involve large plants that are not economically viable for the sole purpose of ODS destruction and synergies with the destruction of other pollutants such as POPs are desirable. They are often part of large chemical, waste incineration or cement facilities. Plasma technologies, as well as other non-incineration technologies are more often compact plants that need high energy input to reach the high temperatures needed for ODS destruction. The Chemicals Technical Options Committee (CTOC) reported in its Progress Report 2010 (CTOC 2011) that many more technologies, than those reported in TEAP (2002), are utilised within 176 destruction facilities in 27 countries. CTOC (2011) reviewed those, not (yet) approved by TEAP according to the minimum standards defined by TEAP as well as country specific performance standards (CTOC 2011), but disclosed no results. Seven emerging destruction technologies that were also mentioned in CTOC (2011) were assessed and partly approved by TEAP in 2011. Technologies for ODS destruction that were approved by TEAP in 2002 and 2011 are presented in Table 4.

Table 4: ODS Destruction technologies with information on applicability and approval by TEAP (2011)

		Applicability				Approved	
	Technology	Foams CFCs	CFCs	Halons	Methyl Bromide	Concentrated CFCs and HCFCs	Diluted Sources (Foams)
Incineration	Cement Kilns	P	Y	P		2002 (XV/9)	
	Liquid Injection Incineration	X	Y	Y		2002 (XV/9)	
	Gaseous/Fume Oxidation	X	Y	Y		2002 (XV/9)	
	Municipal Solid Waste Incineration	Y	X	X			2002 (XV/9)
	Reactor Cracking	X	Y	P		2002 (XV/9)	
	Rotary Kiln Incineration	Y	Y	Y		2002 (XV/9)	2002 (XV/9)
	Porous Thermal Reactor		Y			2011 (XXIII/12)	
Plasma Technologies	Argon Plasma Arc	X	Y	Y		2002 (XV/9)	
	AC Plasma	X	P	P			
	CO2 Plasma	X	P	P			
	Inductively Coupled Radio Frequency Plasma	X	Y	Y		2002 (XV/9)	
	Microwave Plasma	X	Y	P		2002 (XV/9)	
	Nitrogen Plasma Arc	X	Y	P		2002 (XV/9)	
	Portable Plasma Arc		Y			2011 (XXIII/12)	
	SRL Plasma				P		
Other Non-Incineration Technologies	Gas Phase Catalytic Dehalogenation	X	Y	P		2002 (XV/9)	
	Gas Phase Chemical Reduction	X	P	P			
	Solvated Electron Decomposition	X	P	P			
	Superheated Steam Reactor	X	Y	P		2002 (XV/9)	
	Chemical Reation with H_2 and CO_2		Y			2011 (XXIII/12)	
	Thermal Reaction with Methane		Y	Y		2011 (XXIII/12)	
	Catalytic Destruction of fluorocarbons from foam	P					

Y (Yes) = Technology successfully demonstrated for this substance group
P (High Potential) = Technology not demonstrated specifically on this ODS category, but considered likely to be applicable based on evidence of destruction of other substances (i.e., refractory halogenated organics), and on professional judgments (TEAP 2002)
X = not applicable

[9] Maximum emission levels were formulated for dioxins/furans, acid gases, particulate matter, & carbon monoxide (TEAP 2002)

A review of the ODS destruction proposals to the Multilateral Fund for the Implementation of the Montreal Protocol(MLF) showed that developing countries seeking for a local destruction solution, destroy 40 metric tonnes of ODS per year on average, partly processed in several facilities. That is, these facilities are partly run with less than 40 metric tonnes, even below 10 metric tonnes per year (e.g., Cuba).

3.2 Costs

3.2.1 Destruction Cost

Comprehensive information on destruction costs dates back to (TEAP) 2002 and might not be applicable anymore. Therefore no absolute values are given here. Instead, a qualitative evaluation on relative cost is presented in Figure 8. The technology with the lowest costs (according to TEAP 2002) was set to 100% and used as reference.

From the available data, the superheated steam reactor destroys ODS at the lowest cost. Municipal solid waste incineration, although showing second lowest costs, is not recommended for concentrated sources (refrigerants) due to issues with keeping pollutant emissions below the required performance standards.

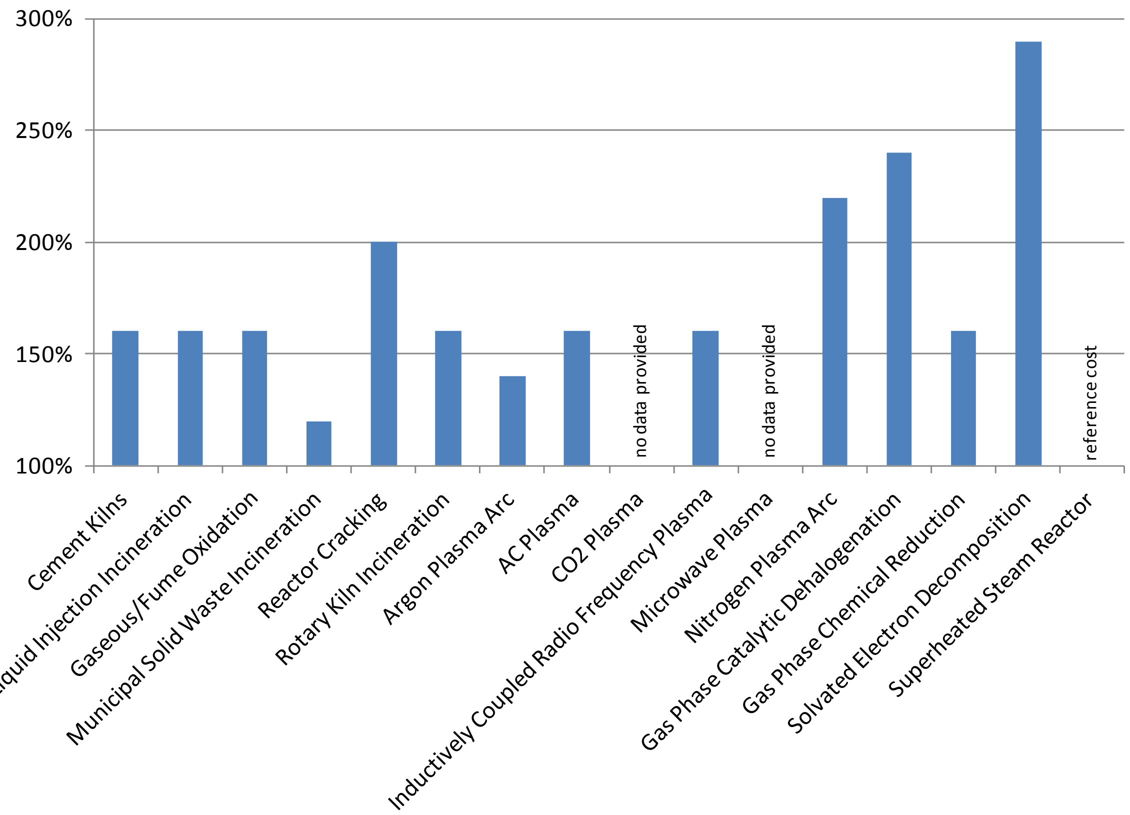

Figure 8: Relative cost of destruction technologies [US$/kg ODS] as presented in TEAP 2002.The superheated steam reactor, being the one with the lowest cost was taken as 100%.

Consequently, from a cost perspective, the most promising destruction technologies in developing countries are (according to TEAP):

- Retrofitted cement kilns
- Liquid Injection Incineration
- Gaseous/Fume Oxidation

- Rotary Kiln Incineration
- Argon Plasma Arc
- AC Plasma
- Inductively coupled radio frequency plasma
- Gas phase chemical reduction
- Superheated steam reactor

Most destruction facilities are located in developed countries, mainly in Japan (approx.80 facilities), the EU (about 50facilities) and the US (> 10facilities, ICF 2008). Recently, developing countries started to build their own destruction capacities such as Brazil, Cuba and Mexico (TEAP 2011). According to ICF (2008), destruction capacities per facility range between 40 to 600 (metric) tonnes/year, depending on the employed technology, with average destruction costs of about 7 US$/kg.

3.2.2 Sector specific cost for recovery and destruction

A comprehensive estimate on different cost items from ODS collection to final destruction was undertaken by TEAP (2009b) for low and medium effort categories. The cost items include the collection of ODS containing appliances or foam pieces and their transport to a recovery facility, the recovery process, the further transport of the recovered ODS to a destruction facility and its final destruction. Although not all cost items might be applicable to local circumstances as collection and destruction might happen at the same site without further transport, Table 5 provides a valuable overview. While the ODS destruction itself is not depending on the subsector and usually represents a minor share of the total cost, the costs associated with collection and recovery can be substantial and highly depend on the subsector and the country-specific situation. Again the distinction between densely and sparsely populated areas is made since the costs for collection and transport as compared to recovery cost are considerably higher in sparsely populated areas. For industrial refrigeration collection cost is considered negligible, because the high amounts of refrigerant contained in the systems result in (almost) no additional cost per kg. Mobile systems can transport their ODS to a recovery facility (which can be the service garage) on its own, therefore no collection cost is assumed.

Table 5 summarises the costs for collection, transport, recovery and destruction on a subsector basis, accounting for the population density. Accordingly, no clear distinction can be made between low and medium effort, since medium effort for one subsector can still be cheaper than low effort for another sector.
Segregation and collection costs are primarily influenced by logistic issues such as available infrastructure and transport distance. Recovery costs differ widely between the various subsectors, depending on the technical process required. Cost for transport of ODS to destruction are the same for all subsectors and usually represent a minor share of the overall costs.

According to Table 5, ODS bank management is the least cost-intensive in the transport refrigeration and mobile AC subsectors. However, it is questionable whether to focus on these subsectors: During service routines, the remaining refrigerant content of the systems is generally recycled on-site, i.e. there is drying and removal of acids. Additionally, these systems are topped up with new refrigerants. At the end-of-life, the disposition of ODS remains unclear, even in countries like Germany. At least no ODS or HFCs from the automotive sector have ever been sent for reclaim to companies such as the Westfalen AG[10].

[10]Technical discussion: „Service und Entsorgung von Kälteanlagen“, September 2014, Umwelthilfe, Berlin

Consequently, the most promising subsectors for ODS bank management of CFC and HCFC with regard to cost-effectiveness are the recovery and destruction of refrigerants in the following subsectors (according to TEAP):

- domestic refrigeration
- commercial refrigeration
- industrial refrigeration
- stationary AC

These findings are not fully consistent with results from ICF (2008). The authors of this study conclude to focus on commercial refrigeration and stationary AC applications only, which are considered as the most cost-effective options.

Table 5: Cost components related to recovery and destruction (US$ per kg ODS), reproduced from TEAP 2009b; colour coding of total costs (lower range) : green for costs below 10 US$/kg, orange between 10 and 50US$/kg and red above 50US$/kg.

Effort Level	Sector	Population Density	ODS Recovered	Segregation/ Collection Cost (US$ per kg)	Transport Costs (Recovery) (US$ per kg)	Recovery Processing Costs (US$ per kg)	Transport Costs (Destruction) (US$ per kg)	Destruction Costs (US$ per kg)	Total Cost (US$ per kg)
Low Effort	Domestic Refrigerators	Dense	Refrigerant	6-10*	6-8	10-20	0.01-0.06**	5-7	27-45
	Domestic Refrigerators	Dense	Blowing Agent			20-30			37-55
	Commercial Refrigeration	Dense	Refrigerant	8-12*	8-10	8-15	0.01-0.06**	5-7	29-44
	Commercial Refrigeration	Dense	Blowing Agent			25-35		5-7	46-65
	Transport Refrigeration+	Dense/Sparse	Refrigerant	--	--	15-20	0.01-0.06**	5-7	20-27
	Industrial Refrigeration	Dense/Sparse	Refrigerant	--	--	4-6	0.01-0.06**	5-7	9-13
	Stationary A/C^	Dense	Refrigerant	1-2^^	--	4-25	0.01-0.06**	5-7	10-34
	Mobile A/C	Dense	Refrigerant	--	--	4-6	0.01-0.06**	5-7	9-13
	Fire Protection	Dense	Fire Suppressant	1-2^^	--	4-25	0.01-0.06**	6-8	11-35
Medium Effort	Domestic Refrigerators	Sparse	Refrigerant	10-15*	30-40^^^	10-20	0.01-0.06**	5-7	55-82
	Domestic Refrigerators	Sparse	Blowing Agent			20-30			65-92
	Commercial Refrigeration	Sparse	Refrigerant	15-20*	40-50^^^	8-15	0.01-0.06**	5-7	68-92
	Commercial Refrigeration	Sparse	Blowing Agent			25-35			85-112
	Stationary A/C^	Sparse	Refrigerant	1-2^^	--	10-35	0.01-0.06**	5-7	16-44
	Mobile A/C	Sparse	Refrigerant	1-2^^	--	4-6	0.01-0.06**	5-7	10-15
	Steel-faced Panels	Dense	Blowing Agent	75-90	5-10	30-40	0.01-0.06**	5-7	115-147
	Block - Pipe	Dense	Blowing Agent	10-15	15-20	30-40	0.01-0.06**	5-7	60-82
	Block - Slab	Dense	Blowing Agent	80-100	5-10	30-40	0.01-0.06**	5-7	120-157
	Fire Protection	Sparse	Fire Suppressant	1-2^^	--	10-35	0.01-0.06**	6-8	17-45

* Very dependent on local collection strategy

** Covering shipment distances of 200-1000 km for destruction

\+ Refrigerant only

^ Assumed on-site recovery

^^ Awareness raising for recovery schemes

^^^ Shipping complete units

ICF (2010) also presented recovery and destruction costs for ODS banks in the EU. Their estimates are based on TEAP (2009b), adapted to European circumstances and complemented with locally collected cost data, afterwards. In the EU, collection and transport of appliances is regulated by national and EU waste legislation, regardless of ODS destruction. Therefore, these costs were not included in ODS destruction cost. ICF undertook a cost assessment for three subsectors, where data availability was best: domestic refrigerators, medium to large commercial refrigeration systems and steel-faced sandwich panels. Costs are originally presented in Euro and have been converted to US$ to allow a comparison[11]. Table 6 summarises the cost data from ICF (2010) and also shows the total cost as estimated by TEAP (2009b).

Table 6: ODS destruction costs (based on ICF 2010). The last column shows cost data as given by TEAP (2009b)

Sector	ODS Recovered	Segregation/ Collection Cost	Transport Costs (Recovery)	Recovery Processing Costs	Transport Costs (Destruction)	Destruction Costs	Total Cost	Total Cost TEAP 2009b
		(US$[a] per kg)	(US$[a] per kg)	(US$[a] per kg)	(US$[a] per kg)	(US$[a] per kg)	(US$[a] per kg)	(US$ per kg)
Domestic Refrigerators	Refrigerant	n.i.*	n.i.*	13.9	0.01	3.75	17.6	27-45
Domestic Refrigerators	Blowing Agent			37.5			41.3	37-55
Medium and Large Commercial Refrigeration	Refrigerant	n.i.*	n.i.*	4.4-5.8	0.01	3.75	8.1-9.5	9-13**
Steel-faced Panels	Blowing Agent	68.8	6.3	25	0.01	3.75	103.8	115-147

* ICF did not include these cost items in its calculation.

** ICF presented cost data for the medium to large commercial refrigeration sector, meaning a supermarket refrigeration system where recovery is done by extracting the refrigerant out of the refrigeration cycle. This procedure is assumed within TEAP's industrial refrigeration subsector. Thus, ICF cost data is compared with TEAP's industrial refrigeration subsector.

[a] ICF presented costs is Euro, which were converted to US$ according to current exchange rate.

The ICF (2010) and TEAP (2009b) cost data are in a similar range. Assumed shorter transport distances due to relatively densely populated countries within the EU and an established take-back system in large parts of Europe explain the slightly lower costs estimated by ICF.

[11]Exchange rate 1 Euro = 1,25 US$, retrieved 19.11.2014 from www.oanda.com

4 Barriers to ODS management and destruction

Even though the destruction of ODS has been on the agenda of TEAP for 10 years (SROC 2005), few activities have taken place and the start of demonstration projects has been much slower than anticipated (UNEP/ExCom 2013). A comprehensive study on ODS disposal (ICF, 2008) has defined five categories of barriers that hinder the effective collection and destruction of ODS in developing and developed countries and gives recommendations for developing countries on how to overcome them. The categorisation was done based on the analysis of ODS destruction management in several developed countries, questionnaires and literature research (ICP, 2008):

- Informational barriers: The understanding of environmental hazards is low and the consequences of releasing ODS into the atmosphere are not known. Therefore, ODS emissions are not avoided.
- Financial barriers: All steps of ODS management and destruction, such as collection, storage, transport, construction and operation of destruction facilities require funding. Additional costs are related to technician training or administrative procedures in the case of export for destruction. If the financial burden of destruction is put on technicians and end-users, losses of ODS are especially high.
- Technological barriers: The recovery of refrigerants and blowing agents requires appliance demanufacturing plants or other special equipment for assembled large systems.
- Logistical barriers: ODS management and destruction requires a complex logistical set-up, consisting of collection points, temporary storage facilities, recycling and destruction facilities and the means for transportation between those. The geographic distribution of ODS can hinder their management as collection and transportation in remote areas are difficult to organise, contribute significantly to the overall management costs and increase the environmental footprint of ODS disposal.
- Legal barriers: the lack of bans on ODS venting and mandatory training and certification of technicians as well as lacking enforcement if such legislation exists, lead to the emissions of banks.On the other hand, there are restrictions to export or import from non-party countries under the Basel Convention or national legislation or extensive administrative procedures that hinder the export for destruction purposes.

Other barriers mentioned are the low public acceptance of waste treatment facilities, in particular waste incineration plants. This is often a problem in developing countries because technical standards to protect the environment and human health (e.g. emission filters, etc. according to best-available technologies (BAT)) are not applied.

Methodology

Since this work was conducted (ICF 2008), the MLF has funded several demonstration projects for the destruction of ODS (Table 7). The project proposals examine the situation regarding ODS destruction in developing countries. The Halons Technical Options Committee (HTOC) has also released its 2010 assessment, which looks in detail at the barriers that were encountered during halon bank management in developing countries (HTOC, 2010).

Table 7: List of documents analysed for the discussion of barriers to ODS management and destruction.

Country/Report	Project	Reference	Barrier categories
Algeria	Cement kiln retrofit	UNEP/OzL.Pro/ExCom/72/19 3 April 2014	Financial, technological, logistical, legal
Cuba	Rotary cement kiln and plasma decomposition (Japanese technology)	UNEP/OzL.Pro/ExCom/62/28 3 November 2010	Financial, logistical
Ghana	Export for destruction	UNEP/OzL.Pro/ExCom/63/31 3 March 2011	Financial, technological
China	Destruction in existing plasma arc technology and rotary kiln	UNEP/OzL.Pro/ExCom/67/23 21 June 2012	Financial, legal
Nigeria	Export for destruction with EOS Climate to El Dorado/ USA	UNEP/OzL.Pro/ExCom/67/27 19 June 2012	Financial, technological, logistical, legal
Colombia	Adaption of three rotary kilns	UNEP/OzL.Pro/ExCom/66/33 19 March 2012	All
Turkey	Export for destruction	UNEP/OzL.Pro/ExCom/66/48 19 March 2012	Financial, logistical, legal
Europe and Central Asia (ECA)	Export to EU for destruction (co-disposal with POPs)	UNEP/OzL.Pro/ExCom/69/32 19 March 2013	All, focus on legal
Georgia	Export for destruction (co-disposal with POPs)	UNEP/OzL.Pro/ExCom/69/26 13 March 2013	All
Brazil	Test burns at two out of seven local hazardous waste management facilities	UNEP/OzL.Pro/ExCom/72/23 14 April 2014	Informational, financial, logistical
Mexico	Export to US for destruction	UNEP/OzL.Pro/ExCom/63/42 9 March 2011	Financial, technological, legal
Lebanon	Export to Europe for destruction	UNEP/OzL.Pro/ExCom/73/41 10 October 2014	Logistical, legal
African countries (6 LVCs in Central Africa)	Technical assistance to develop methodology for LVCs to quantify stocks of unwanted ODS	UNEP/OzL.Pro/ExCom/67/Inf.2 26 June 2012	All
Nepal	Technical assistance to export the ODS to US for destruction	UNEP/OzL.Pro/ExCom/70/54 5 June 2013	All
Report on progress and experiences gained in demonstration projects of unwanted ODS		UNEP/OzL.Pro/ExCom/70/54 5 June 2013	All
HTOC, 2010	Report of the Halons Technical Options Committee	http://ozone.unep.org/Assessment_Panels/TEAP/Reports/HTOC/index.shtml	All

Whilst the ICF study (2008) mainly uses experiences from developed countries as a basis, all barriers listed in the documents from Table 7 are regarding the situation in developing countries. Both the MLF proposals and the HTOC report (2010) were used to analyse barriers to ODS destruction according to the categories given in ICF (2008) with the aim of answering the following questions:

➔ Are the barriers still the same 6 years after the first assessment? Are barriers based on experiences in developing countries different?

- → Are the recommendations from ICF (2008) still valid? Could recommendations based on the analysis of the situation in developed countries be confirmed during the project preparation phase in developing countries? Do they have to be adapted?

Barriers mentioned in the documents were grouped into the five categories mentioned in ICF (2008) and condensed. The points are ordered according to the frequency they occurred and the importance they were given in the documents. The topics mentioned most and stressed more than others were therefore listed first.
The projects are all demonstration projects with different solutions for ODS bank management: Technology introduction/conversion, export for destruction, financing of destruction activities and data collection. From the HTOC (2010) only those barriers that can be related to all ODS were regarded.

During the analysis, the barriers mentioned in ICF could be confirmed. However, the high number of ODS destruction projects and the focus on developing countries have shown that there are several points that have to be considered additionally.

4.1 Informational barriers

- Lack of ODS banks inventory: There is too little data or no possibility to verify existing data or conduct comprehensive inventories
- The public awareness of the environmental impact of ODS is very low
- There is a lack of knowledge regarding the treatment of ODS (quality analysis regarding chemical compounds/contamination, destruction processes, export procedures, technical standards) as well as how to organise ODS waste collection, recovery, storage, transport and qualification needs for technical personnel. Further, often there is no experience or information how to establish a financing mechanism
- There is a lack of trained operators and difficulty to sustain qualified personnel. The lack of trainings and workshops is mentioned repeatedly.
- There is a lack of knowledge regarding the treatment of ODS (quality analysis regarding chemical compounds/contamination, destruction processes, export procedures)
- The necessary involvement of many different stakeholders (e.g. producers and importers of ODS containing appliances, waste sector, national ozone units, cement industry) is difficult. Responsibilities are often not clearly defined, this is especially problematic in the case of ODS bank management as it is a cross-sectoral topic involving different environmental areas.

Box 3: Additional insights from MLF proposals

Many countries could not quantify the expected amount of ODS within the country and therefore found it difficult to decide on adequate management options. The training needs for technicians and other stakeholders are higher than previously thought.

4.2 Financial barriers

- High costs for the destruction of ODS are highlighted by all proposals and reports. On the one hand, these relate to building destruction facilities, the retrofit of existing facilities and buying equipment (e.g. conversion of cement kiln, dedicated destruction facilities, small portable destruction units). These have to meet TEAP standards (TEAP 2002) and emission monitoring has to be established.
  On the other hand, operating costs are extremely high and project costs can be exhausted with the purchase of equipment. Electricity, fuel and raw materials are needed. Because of the low calorific value of ODS, additional fuel has to be burnt in order to reach temperatures high enough for destruction. In one case, existing facilities could not be run at full capacity because of high operating costs. The costs of ODS inventories, which are used to identify remaining ODS volumes are also very high.
- In low volume countries (LVCs), not even small portable destruction units are economically feasible.
- The long-term operation of ODS destruction projects is often in danger. Especially, but not only in LVCs, there are not enough ODS banks to sustain their operation. Because of uncertain/unfinanced collection activities, future waste streams cannot be guaranteed.
- Many projects plan financing via voluntary carbon markets in the USA where the destruction of ODS can generate carbon credits. Financing through the carbon markets always requires seed money and this can be a substantial amount. This is only possible in the USA, resulting in high transport costs for some countries and high administrative effort as the USA are not part of the Basel Convention. The financing of these projects is bound to the carbon markets and their recent downturn means considerably less income.
- The infrastructure costs for collection, storage and transport of ODS wastes are high. Costs for collection are not financially supported by the MLF. Storage and transport require cylinders and ISO certified tanks. Special equipment is needed for the recovery of ODS. Storage space can be very expensive and unplanned for, e.g. if there are delays in the construction of destruction facilities. Depending on the location of destruction facilities, transport costs can vary.
- Costs for management and overhead, such as for administrative procedures, are considerable when ODS wastes are exported for destruction. Seed money is always needed.
  Technician training, including regular refresher trainings are necessary and financing has to be provided.

Additional insights from MLF proposals

For countries with lower ODS waste streams, not even small dedicated destruction facilities are financially feasible (e.g. Nepal, Ghana). It is important not to neglect the operating costs of these facilities. If funds are exhausted by purchasing equipment, long-term operation is not possible.

Using the carbon market as a financing tool for the destruction of ODS has also resulted in problems. Not only is the varying carbon price a concern, the necessary seed money to finance the export can be very high. At the moment, carbon credits can be gained only in the US, resulting in legal and logistical problems.

4.3 Technological barriers

- Because of the high costs of dedicated destruction facilities, many projects focus on the conversion of cement kilns. This is dependent on available cement kilns in the country and suitable locations. The ODS destruction is thereby linked to cement production. Operators of cement kilns are sometimes not willing to convert as the presence of chlorine in the cement kiln can lower the quality of the cement and affect the productivity of the kiln as the crust thickens and reduces the interior of the kiln. The dosage of ODS into the kiln is very important in order to prevent this[12].
- There is a lack of technical reports, protocols and manuals for the collection, recovery, storage, local destruction and purity testing of ODS.
- The certification of facilities is needed to meet the 99.99% destruction removal efficiency (DRE) limit. Monitoring of toxic emissions is required, leading to additional costs, personnel needs and technical equipment.
- In order to extract blowing agent from foam, special equipment or appliance dismantling plants are necessary.
- Off-the-shelf destruction equipment does not always work in high ambient temperatures. Equipment might have to be shipped back to the manufacturer for repair.
- The handling and storage of compressed gas cylinders requires additional training.
- An often observed inefficient ODS recovery process from appliances reduces the expected waste stream of ODS.

Additional insights from MLF proposals

The conversion of cement kilns is seen by many countries with relatively small waste streams as being the best solution financially if destruction within the country is considered. However, their conversion is related to technological problems, often because of lacking knowledge and training of operators. Ambient temperatures in developing countries are often high, which could lead to problems with the equipment. Missing protocols, instructions and reporting documents were highlighted several times.

4.4 Logistical barriers

- The servicing and maintenance sector in many developing countries is not formally organised. There is no institutionalised waste collection, especially when it comes to domestic appliances containing ODS. This means that the informal sector is responsible for waste collection, making it difficult for the waste to reach the ODS management/destruction facilities. The incentive to deliver to facilities is low when the financial gain is higher at other recycling routes. In cases where there is a collection system, it does not work well in remote areas.
- Because of slow destruction activities or slow export for destruction, ODS are often accumulating. Setting up storage is seen as a problem for several projects, especially low storage capacity and space. Cylinders and the right recovery equipment for ODS are missing. This leads to continuous leakage until there is little ODS left. Leakage rates from cylinders are given with 10-12 % per year(UNEP/ExCom 2013)
- There is no destruction facility or existing facilities are at disadvantageous locations. These are then not running at full capacity because the ODS waste cannot reach them.

[12] The chlorine also corrodes the refractionary bricks in the long term, which was mentioned as a negative aspect of cement kiln retrofit (MOP to the Montreal Protocol, Paris, November 2014)

- A lack of cylinders and dedicated vehicles make the transport of ODS difficult. This influences the feasibility of regional solutions.
- The exchange of data between different stakeholders is inadequate and there are no electronic databases to monitor waste movement and storage requirements.
- Missing focal points or a frequent turnover as well as a lack of human resources at all levels of management and execution hinder the sustainable establishment of ODS destruction logistics.

Additional insights from MLF proposals

The specific problems of the collection of ODS waste were not listed very often as the demonstration projects focus on the destruction of ODS waste. It was however often described that the continuous waste stream of ODS was in danger because further collection activities were not taking place or could not be financed. Storage was listed as an unexpected cost factor for both necessary equipment and space.

4.5 Legal barriers

- Bans on ODS venting, mandatory collection and recovery of ODS, mandatory technician training and certification and high health and safety standards as well as standards for the safe operation of ODS destruction facilities are necessary. Even if such regulations exist, there is often a lack of enforcement.
- The Basel Convention restricts the export of ODS for destruction if one of the involved countries is not a Party or countries have regional agreements/national legislation that prohibit the import and export of hazardous waste. If at all possible, high efforts are necessary to gain exemptions for an import or export ban or to fulfil all Basel Convention requirements for the export of hazardous waste. It can take several months to gain a permit for export licence (prior informed consent procedure) under the Basel Convention. In order to transport ODS waste, a license is necessary and if the transport takes place within the European Union, the European Agreement concerning the International Carriage of Dangerous Goods by Road[13] applies.
- Countries or even provinces within one country (such as China) can have different definitions of hazardous waste, making it very difficult to examine national policies and regulatory infrastructure.
- The fulfilment of HPMPs has priority over ODS destruction activities as it is required in order to comply with the Montreal Protocol.

Additional insights from MLF proposals

Lack of health and safety standards was also mentioned as a barrier to the safe destruction of ODS. Otherwise, the findings of ICF (2008) were confirmed and legal barriers seen as an important factor in ODS management and destruction.

[13]http://www.unece.org/trans/danger/publi/adr/adr_e.html; accessed 27 November 2014

4.6 Other barriers

Other barriers mentioned were:

- The development of regional destruction projects was seen as difficult if there is no government support. A common financial, regulatory and legal structure of participating countries would be extremely helpful.
- The experience with ODS disposal projects in developing countries is very limited.
- Problems have been encountered when trying to link initiatives for chemical waste management with those for ODS disposal.

5 Important policy measures to promote ODS management

The most important factors which decide about the success of ODS management in developing countries, are the creation of financial incentives for returning ODS or ODS containing equipment, and a legislation for treatment of ODS waste. Consequently, promising policy measures are related to financial mechanisms of ODS management; reclamation or destruction should not impose a cost burden. At least, end-user should not have to pay directly for reclamation or destruction activities. In contrast it should become attractive, i.e. setting an economic incentive in order to motivate end-users and the informal sector to return ODS containing equipment, at least in the appliance sector. However, the higher the economic incentive, the more costly the implementation of the ODS management. This is a typical trade-off situation. Other political mechanisms exist, such as Extended Producer Responsibility (EPR) schemes. They try to reduce end-of-life treatment costs and thereby give an incentive for the production of environmentally friendly technology in the long run that does not rely on hazardous substances such as ODS or HFC. Using environmentally friendly technology based on natural refrigerants, reduces the post-consumer costs. EPR schemes shift financial responsibility from municipalities to producers, which is in line with the Polluter Pays Principle (PPP). PPP is a principle where the costs of pollution will be paid by those who cause it.
Other key aspects of a successful ODS bank management are a clear definition of responsibilities and the establishment of technical standards for the destruction process of ODS.

The Hydrochlorofluorocarbon Phase Out Management Plans (HPMP), which implement the policy measures of the Montreal Protocol, intend to phase out the consumption and production of HCFCs. A similar approach was undertaken by the EU for HFC, both prevent a new accumulation of ODS and HFC banks respectively. Such policy measures are of central significance to avoid future negative environmental impacts. However, they will not be discussed in this chapter, as the focus is on how to deal with existing ODS banks in developing countries.

5.1 Regulations and enforcement

ODS management will not work without proper regulations[14] and its enforcement. Three legal requirements are considered as crucial:

1) ban the venting of ODS
2) mandatory recovery of ODS during servicing
3) mandatory recovery of ODS at end-of-life of equipment

There are higher chances for a successful ODS management, when there are already commitments to proper waste management. There is a strong linkage between ODS management and waste management, which is a chance and a challenge at the same time. While ODS, persistent organic pollutants (POPs) and other hazardous substances such as polychlorinated biphenyl (PCB) are institutionally often managed at the same department, this is not the case for solid waste and Waste of Electrical and Electronic Equipment (WEEE) and needs interdepartmental cooperation. In case the infrastructure, the regulations and awareness for handling waste or Waste of Electrical and Electronic Equipment (WEEE) are already in place, it seems as a fairly small step to introduce the proper handling of the ODS within the equipment. On the other hand it requires strict allocation of responsibilities. Such processes of the coordination and planning can be a real challenge, especially in developing countries.

[14] We use the term regulation instead of legislation in most cases, because regulations usually provide more specific information for how the broad legislative objectives will be met. Legislation is only sporadically used in the document as a synonym for law.

A success factor is to collaborate with the affected industry sectors in order to find the ideal specifications within the regulation (ICF 2008a) and to ensure comprehensive involvement of the different stakeholder groups.

The EU has passed a range of regulations and directives to address a proper ODS and F-gas (HFC, PFC, SF_6) management, which complement the waste management. The relevant regulations and directives are listed below.

Handling of ODS and F-Gases

- Regulation (EC) 1005/2009 on substances that deplete the ozone layer
- Regulation (EC) 842/2006 on certain fluorinated greenhouse gases
- Regulation (EC) 517/2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006

Waste management, classification and shipment

- Directive 2008/98/EC on waste and repealing certain Directives
- Regulation (EC) 1013/2006 on shipments of waste

Waste stream specific directives which are related to ODS

- Directive 2002/96/EC on waste electrical and electronic equipment (WEEE) + recast 2012/19/EU
- Directive 2000/53/EC on end-of life vehicles
- Directive 2008/98/EC on waste addresses amongst others recycling targets for construction and demolition waste,

Regulation (EC) 1005/2009[15] is also called the "ODS Regulation" and defines requirements for the handling of ODS throughout their use. For example Article 22 says:

"Controlled substances contained in refrigeration, air-conditioning and heat pump equipment, equipment containing solvents or fire protection systems and fire extinguishers shall, during the maintenance or servicing of equipment or before the dismantling or disposal of equipment, be recovered for destruction, recycling or reclamation"

The Regulation (EC) 517/2014[16] deals with F-gases and replaces the Regulation (EC) 842/2006 and has entered into force in January 2015. The prohibition of venting F-gases for example is defined in Article 3; recovery requirements are given in Article 4 and the reporting requirements of recovered gas is defined in Article 6.

In developing countries, only few have specifically addressed ODS management within legislation, such as bans of venting ODS, recovery of ODS during servicing and at end-of-life of equipment or more advanced regulations for e-waste. There is no global overview about ODS legislation on a country basis, information has to be gathered individually.

Enforcement is as important as the regulation itself. Regulation can only be successful if there is a credible threat of penalty in case of violation. The enforcement is also a weak point in many developed countries, mostly limited to random checks[17] (cf. chapter 4). It is the national enforcement authorities who are responsible for the enforcement of

[15] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:286:0001:0030:EN:PDF; accessed 1 December 2014

[16] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2014.150.01.0195.01.ENG; accessed 1 December 2014

[17] UBA symposium Sindelfingen, March 2014

EU legislation. There is also the European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL), promoting the effective implementation by information exchange, the development of national networks etc.

A reporting system for ODS is required to have a certain control of the government programmes and to evaluate the success of ODS management. For example the Regulation (EC) 1005/2009 requires annual reporting of ODS from the EU member states itself (Art. 26) but also from companies, more specifically producers, importers and exporters of controlled substances (Art. 27). Accordingly, companies shall communicate to the Commission and the competent authority of the Member State the type of ODS and the amount produced, imported and exported. The reporting obligations also include the quantity of recycled, reclaimed or destroyed ODS and the technology used for the destruction (e.g. Art. 27-f). Under Regulation (EC) 1005/2009 there are further reporting obligations for operators of ODS containing equipment (Art 23, paragraph 2) depending on the charge size. Data to be recorded are for example the quantity and type of controlled substances added to the equipment, the quantity recovered during maintenance, servicing and final disposal. In Germany, the “Chemikalien-Ozonschichtverordnung” specifies some of these requirements, for example that these records must be kept for at least five years and have to be disclosed to the competent authorities upon request (§ 4).

Record keeping and reporting requirements should at least focus on recovery operators that must submit annual reports, indicating the recovered amounts. But even in developed countries this is not implemented optimally. The EU and Japan for example have strict regulations and enforcement, but the refrigerant recovery rate in the commercial refrigeration sector is estimated at 30 % in Japan only (IFC 2008). In developing countries even lower recovery rates have to be expected (ICF 2010a).

Technician training and certification

Technician training and certification may not be considered as a policy measure but as an accompanying measure when implementing ODS regulations. It is considered crucial in order to succeed with the regulatory framework. This is why this issue also has been incorporated in the regulations and directives of the European Union, for example in Regulation (EC) 1005/2009 (Art. 23 Abs. 4). Accordingly leak checking of the equipment may only be carried out by certified personnel.

Proper technician training is indispensable to increase recovery and to guarantee proper handling and prevent emissions of ODS. Most effective are "train the trainer" programmes which multiply the effect within developing countries. Technician training is already an accompanying measure under the currently implemented HPMP and thus can be extended and enforced with ODS bank management activities.

Within the GIZ Proklima activities, around 3,700 technicians were trained in Africa, approximately 25,000 in Brazil and 10,200 in India (status October 2014). Still, it is a costly issue and often difficult to measure the cost-effectiveness.

5.2 The Basel Convention

Parties to the Basel Convention commit themselves to reduce hazardous waste and transboundary movements (TBM) of hazardous wastes as much as possible. TBM are allowed if environmentally sound management/destruction is not possible within the country, but certain conditions have to be met. TBM have to occur according to the Prior Informed Consent (PIC) procedure. This means that, the country of export has to implement the notification procedure and after receiving the consents of the competent authority of dispatch, transit and destination, the TBM can take place. After the TBM, a confirmation of disposal has to be sent back to the competent authority of the exporting country. Extensive information has to be supplied by each participant of this PIC (see Annex). Each movement has to be reported to the secretariat of the Basel Convention.

Competent authorities are the chosen government authorities that receive and respond to notifications on TBM. Focal points receive and submit information necessary for TBM. Thus the infrastructure of focal points and competent authorities can assist with the export of ODS for destruction. The secretariat of the Basel Convention is informed about the assignment of competent authorities and focal points.

The issued certifications of destruction can prevent malpractice and the reporting system guarantees environmentally sound management.

However, the Basel Convention can also be a restriction when it comes to the export of ODS for destruction. This is the case if the transport between Parties and non-Parties is necessary or if the involved parties have different requirements for the import of hazardous waste due to stricter national legislation or different definitions of hazardous waste. A lot of paperwork is involved with TBM and this can be a lengthy and expensive process. Furthermore, communication between the secretariats of the Montreal Protocol and the Basel Convention show that not all countries have defined ODS as hazardous wastes and some countries have no national legal definition at all (UNEP, 2009). Article 4 (1) of the Basel Convention states that countries can pass national legislation that is stricter than the Convention, for example banning the import of hazardous wastes. According to ICF (2008), 45 countries have banned the import of ODS completely. The official webpage from the Basel Convention provides a list of countries with import bans after 2005[18]. An up-to-date list can be requested from the secretariat of the Basel Convention.

5.3 Extended producer responsibility

Extended Producer Responsibility (EPR) schemes were introduced in the early 1990s in European countries and now have become an efficient waste management policy around the world, leading to increasing recycling rates. EPR means that producers are given responsibility for their products at their end of life. EPR schemes generally 1) increase collection and recycling rates of the products, thereby saving costs and 2) they shift financial responsibility from municipalities to producers who then have the responsibility for handling all waste components of the product. Shifting the financial responsibility to producers is an incentive for the production of environmental sound products. For example the end-of-life treatment of RAC products, based on natural refrigerants, are less cost intensive. Incentives for the actors operating the EPR schemes might be introduced to increase the effectiveness of the policy approach. In the long run, producers forward the additional costs caused by EPR schemes, or at least parts of the costs, to end-user. Consequently, the costs are partly paid by the consumers and not by the tax-payer.
The guidelines from the OECD (OECD, 2001) strongly promoted the process of implementing EPRs in many countries of the world. Also the European Commission published a report that reviews the implementation of EPR schemes in the 28 member states to come up with guiding principles on how to design efficient EPR schemes (European Commission, 2014).

In the European Union, there are Directives which require the use of EPR policies for packaging, batteries, End-of-Life Vehicles (ELVs) and Electrical and Electronic Equipment (WEEE). Both domestic refrigerators and air-

[18]http://www.basel.int/Countries/ImportExportRestrictions/tabid/1481/Default.aspx

conditioners fall into this last category and are therefore covered by EPR schemes in Europe. France specifically formulated and EPR policy for fluorinated refrigerant fluids (French Ministry of Environment, 2014).

Considering ODS bank management, this mechanism is particularly interesting because both refrigerants and foam blowing agents in domestic appliances are affected. EPR schemes are considered the most promising solution in the appliance sector to reduce unwanted ODS waste at the EOL of RAC equipment. Within the RAC sectors, EPR schemes seem particularly interesting for:

- Residential and commercial air conditioning equipment
- Small chiller
- Domestic refrigerators
- Stand-alone units in commercial refrigeration

A number of developing countries have introduced EPR schemes (OECD, 2014). Table 8 provides a regional overview about EPR schemes in developing countries. In Asia EPR schemes are working with varying success while in Africa EPR schemes are not implemented well, with the exception of South Africa. However, some African countries have drafted e-waste bills, such as Ghana and Kenya, which include EPR schemes.

Table 8: Regional overview about established EPR schemes in developing countries (OECD, 2014)

Latin America and the Caribbean	Asia	Africa
• Chile • Mexico • Brazil • Argentina • Colombia	• Korea (good experiences) • China, India, Indonesia (experiencing problems) • Thailand (mostly rely on voluntary participation of producers)	• South Africa

To enforce EPR schemes, a mix of measures from four intervention areas might be applicable (Figure 9). The measures can be implemented as mandatory policies (by government) or on a voluntary basis by the producers. The selected mix of measures will depend on the country's situation and the focus of EPR schemes. Figure 9 introduces the different aspects of EPR schemes.

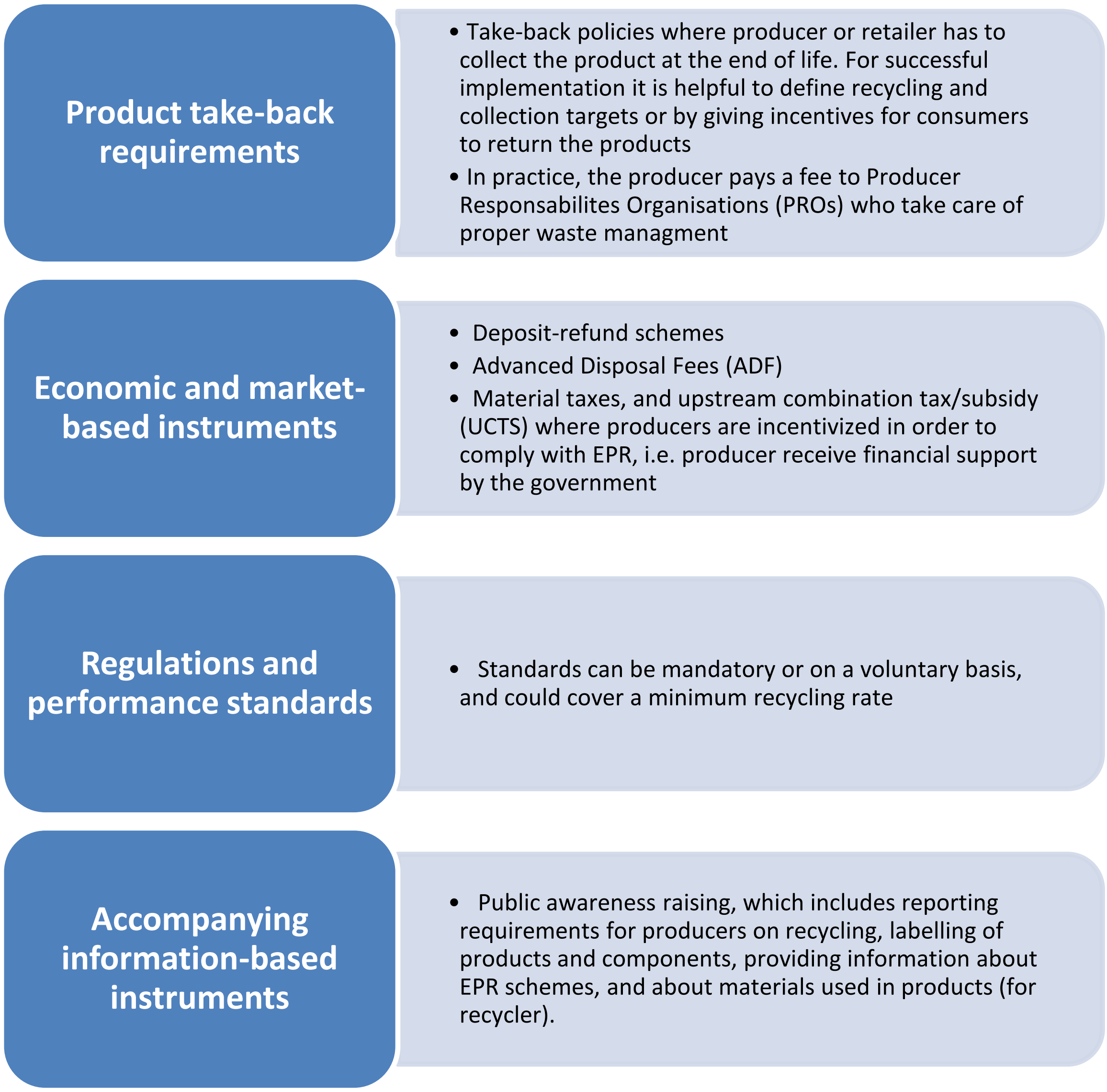

Figure 9: EPR scheme, described as a mix of instruments from four intervention areas rather than a single policy. OECD 2014, modified.

Programmes on a voluntary basis are also referred to as “stewardship programmes” and are common in the US. Experience, however, has shown that this concept has not succeeded, particularly in the field of ODS bank management: producers did not take physical or financial responsibility for recycling or for environmentally sound disposal. This is why the release of ODS continued, despite the introduction of stewardship programmes (Nicol & Thompson 2007). Programmes on a voluntary basis only seem to have a success chance, when regulatory restrictions and bans are discussed among policy makers with a certain probability to be implemented.
EPR schemes and stewardship programmes have similar ideas in extending responsibilities for waste management but differ radically in their effectiveness.

5.3.1 Potential application of an EPR scheme in ODS bank management

To illustrate the application of the above intervention areas, an example is given for ODS bank management in the appliance sector. It is advisable to use a measure from the **"product take-back requirements"**. However, this will not be enough in developing countries, where ODS waste collection is mainly done by the informal sector. The informal waste collectors sell the different appliance components on the black market. Thereby they involuntarily release refrigerants and foam blowing agents. Thus it must become attractive for end-users and the informal waste collectors to return their equipment. This can be achieved by establishing take-back systems. When a new system is handed out for the return of an old system, take-back systems are referred to as replacement programmes, typically known as "cash for clunker" or "new for old" programmes. Replacement programmes are incentivising the exchange of appliances. The new units should comply with certain pre-defined performance standards such as Minimum Energy Efficiency Standards (MEPS), i.e. after introducing measures from the field **"regulations and performance standards".** The idea of replacement programmes is to promote energy efficient and environmental friendly technology to reduce the energy demand, easing the strain on the electric grids and to achieve climate goals. There is a high creative leeway when designing the financial concept. The new units can be distributed for free (e.g. domestic refrigerator in Brazil) or cheaper by giving incentives. The costs for these programmes are ideally covered by the producer or alternatively by the utility providers, potentially also by development banks (KfW, ADB), GEF, NAMA Facility etc. The money could also be taken from an HFC tax (**"economic and market-based instruments"**). Obviously, there will not be success without providing appropriate information. **"Accompanying information-based instruments"** are an essential part to provide the appropriate information about such mechanisms and to raise awareness, focusing on the end-users and all stakeholders involved. This example demonstrates the need for a mix of measures from different intervention areas.

Box 4: EPR schemes

- Extended Producer Responsibility (EPR) is defined as “an environmental policy approach in which a producer’s responsibility for a product is extended to the post-consumer stage of a product’s life cycle”, i.e. after end-of-life (2001 OECD Guidance)
- Producers will incorporate the costs for proper end-of-life management of their product. In practice, these costs are generally transferred to the consumers of the product. Public spending (i.e. taxpayers’ money) will thereby be reduced. In the long run, consumers of affected products will pay for the end-of-life treatment instead of taxpayers
- EPRs are recognised as one of the most effective and promising policy instruments to improve recycling and to reduce landfilling
- EPR schemes are most suitable for small end-user appliances
- EPR schemes are a mix of several instruments from the following intervention areas: Product take-back requirements, economic and market-based instruments, regulations and performance standards, and accompanying information-based instruments
- EPR schemes are believed to generate various other benefits such as increased technological and organisational innovation

Main advantage of EPR schemes in ODS bank management: this policy approach establishes a sustainable financing mechanism in the appliance sector (ODS containing equipment) and gives an incentive for manufacturers to produce environmental friendly products without ODS.

5.3.2 Challenges facing EPR schemes

Most challenges facing EPR schemes in developing countries are related to governance and administrative issues. There is a need for clear and non-overlapping roles and responsibilities of different actors. As mentioned above, EPR schemes are a flexible policy approach, and there is no standard solution with regard to the financial responsibility and allocation of responsibility among stakeholders. A participatory approach with the relevant stakeholders is necessary to define responsibilities: Producer Responsibility Organizations (PROs), producers, importers, collectors and recyclers, municipalities and consumers must agree on commitments. The resulting challenge is permanent monitoring and control by public authorities. This is also a means to avoid that certain producers do not adequately comply with their obligations under EPR (free-riding). This is most often observed when more than one PRO exists under one collection scheme. However, several PROs are considered as key for a vital competition between them to reduce costs. This was observed after the "Duales System Deutschland (DSD)" lost its monopoly in Germany and the market was opened to new entrants. In consequence the cost for waste management was reduced by 50 %.

In developing and newly industrialised countries that have not established EPR schemes in the waste sector yet, the key challenge is the transition from informal to formal waste management. The informal waste sector can always operate at cheaper costs compared to official recyclers; informal recycling has become a lucrative business in many countries. In India for example, more than 95 % of e-waste are estimated to be processed by the informal sector (OECD, 2014). Waste picking is sometimes the only income source for the poorest sections of the population. In order to transform the informal to a formal waster sector, it is the task of policy makers to create alternative employment opportunities and social frameworks for those whose subsistence is based on that sector. In practice, however, this is often largely ignored. A promising approach is to create incentives for the informal sector, as happened for example in Ghana. In this example the health insurance for informal waste pickers is paid by a formal waste management company, when informal waste pickers collaborate with the company and supply a certain amount of waste each month. The lack of a formal recycling infrastructure is often considered as a barrier in many developing countries (e.g. Manomaiviboo et al., 2007). Finally, a solution for orphan products must be found, i.e. products that entered the market before the establishment of EPR systems, and whose producers are no longer in business. Similar, solutions must be found for no-name products or those that illegally have been imported.

Finally, EPR schemes generally work best when few players (producers or importers) are involved (MLF 2008). EPR schemes generally tackle existing ODS banks in appliances, that is equipment that has entered the market before the EPR scheme was introduced. Indeed, already recovered ODS (stored in cylinders) are not covered, where additional financial resources are needed. However, mostly little amounts of already recovered ODS (stored in cylinders) are found in developing countries.

5.4 Voluntary carbon market

The global carbon market can be divided into the compliance and the voluntary market. The focus of this chapter is on the voluntary carbon market, because it is considered as a potential financing mechanisms for ODS management and destruction. Some critical issues about the voluntary carbon market will be addressed at the end of this chapter.

The compliance market is linked to the Kyoto Protocol, helping governments to achieve their Kyoto Protocol targets. The Kyoto Protocol only covers the Kyoto gases (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3), therefore ODS cannot be covered by the compliance market and the only chance to gain credits for ODS destruction is the voluntary market.

The European Union Emissions Trading System (EU ETS) is an example for a regional compliance market, i.e. a market-based approach to control GHG emissions. As a cap-and-trade system, the EU ETS defines an emissions cap with regard to the total emissions. Within that limit, participants in the system can buy and sell allowances as they require. There are more than 11,000 energy and industry facilities in 31 countries that participate at the EU ETS, covering ca. 45 % of the EU's greenhouse gas emissions[19]. The carbon price is defined by demand and supply as well as the willingness to pay per EU allowance (1 allowance (EUA) equals 1 tonne of CO_2eq). Another regional

[19]http://ec.europa.eu/clima/policies/ets/index_en.htm; 21 November 2014

compliance market is found in the US: The Regional Greenhouse Gas Initiative (RGGI). It covers electricity generators in ten US states and is much smaller than the EU ETS.

In contrast, in the voluntary carbon market organizations and individuals can offset GHG emissions on a voluntary basis. Here the demand is given by the buyers' interest and not by any regulation. The main motivation to participate in the voluntary carbon market is the reputation and green image of companies, which is becoming more important as climate change entered the public debates (ICF 2008b). A few years ago, the voluntary carbon market was first described as a potential mechanism for ODS management because of the high GWP of ODS (e.g., Hamilton et al. 2009, ICF 2010).

The voluntary carbon market contributes ca. 1 % to the total global carbon market (Word Bank, 2009).

There are currently three possibilities to generate carbon credits for ODS destruction projects within the voluntary carbon market[20]:

- Chicago Climate Exchange (CCX): offers a project protocol to guide ODS destruction projects
- Voluntary Carbon Standard (VCS): published a series of eligibility criteria for ODS destruction projects; halons are not covered by this standard; the methodology does not apply to the destruction of stockpiled ODS
- Climate Action Reserve (CAR): provides methodologies for ODS destruction in form of two offset project protocols

Nearly 50% of the voluntary market volume is verified by the Voluntary Carbon Standard, 10% by the Climate Action Reserve and 12 % by the Gold Standard (ICF 2010). In 2013 CAR issued 9.3 Mt CO_2 credits from which 4 Mt CO_2 credits came from ODS. Among the ten largest projects approved by CAR, there are already three ODS projects with a total of 3.3 Mt CO_2 credits. The CCX and the CAR have adopted protocols for ODS destruction in US facilities that meet the US EPA's Clean Air Act standards.

According to ICF (2010), the ODS potentially available and eligible for destruction is in the magnitude of 200 Mt CO_2eq in the year 2015 (excluding ODS from the EU and HCFCs) assuming a 50 % recovery and destruction rate, which is unrealistic. Assuming a 10 % recovery and destruction rate, which is still fairly optimistic in developing countries (see chapter 3), translate into 40 Mt CO_2eq in the year 2015. This figure must be considered in relation to the projected volume of the voluntary market, which is given with ca. 350 Mt CO_2eq in the year 2015. Thus ICF (2010) assumes that ODS destruction projects would not overwhelm the voluntary market.

5.4.1 Challenges facing the voluntary carbon market

In 2009, the voluntary carbon market was expected to grow by ca. 15 % per year over the next decade (Hamilton et al. 2009). However, the volume and value remained relatively stable since 2009, while the carbon price even declined since 2008 to a low level of currently 4.8 US$ (Figure 10). Considering the 2012 to 2013 changes, the volume and value of the voluntary carbon market decreased by 26 % and 28 %, respectively (Trends' Ecosystem Marketplace 2014).

[20] There are more standards for carbon offsetting such as the Gold Standard, however, only three standards offer carbon credits for ODS destruction.

Considering this trend it seems questionable whether this mechanism provides the necessary revenues to finance ODS bank destruction, particularly keeping substantial seed funding in mind to arrange the export of ODS for final destruction (see chapter 4).

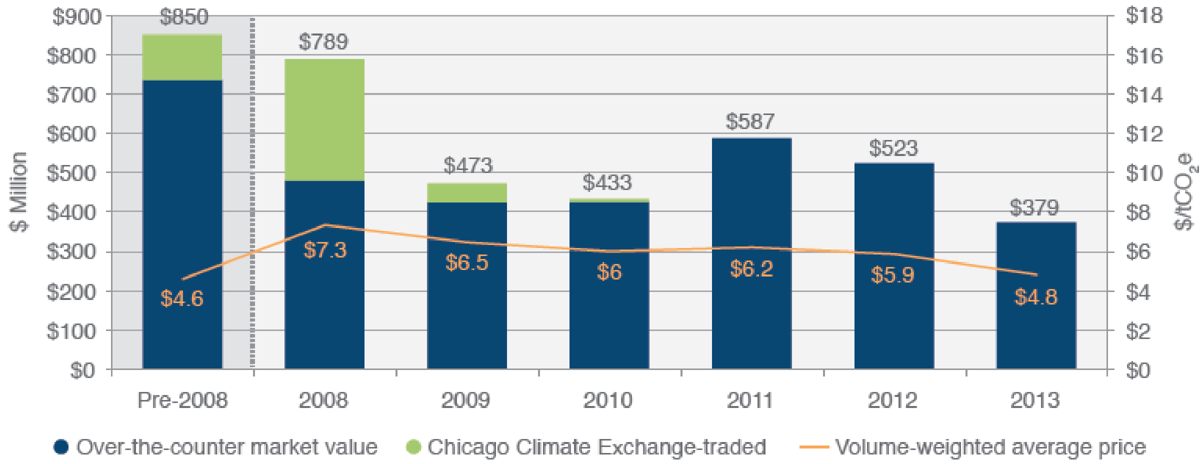

Figure 10*: Historical market-wide values and average prices, from Forest Trends' Ecosystem Marketplace (2014)*

While the debate around the VCS protocol has resulted in somewhat more stringent requirements, both the VCS and the CAR protocols are still clearly in opposition to European environmental standards: There is reasonable cause for concern that the voluntary carbon market gives perverse incentives to initially produce ODS (instead of avoiding ODS), to maximise benefits from the revenues. This concern is given for historical reasons, where for some CDM projects it was claimed to have intentionally increased the amount of HFC-23, a by-product from the R-22 production, in order to maximise the available CDM benefits, leading to millions of carbon credits being issued with little or no benefit to the climate (Baietti et al. 2012). The EU and other Kyoto parties from developing and developed countries observe the generation of credits from ODS and HFC-23 destruction with great reservation.

Apart from this debate, there is also space for other illegal activities, for example when ODS is exported from one country with legislation that requires destruction to another that does not. Actors within countries that lack destruction obligation could again export the ODS to generate carbon credits, thus making money out of it.

Another barrier for small countries with little ODS quantities, that want to use voluntary carbon market as a financing mechanism for ODS bank management, refers to economies of scale; large volume projects achieve a better cost-effectiveness. Smaller countries with little ODS banks and waste streams probably cannot afford ODS management via the voluntary carbon market. Small-scale projects where only 1,000 refrigerators can be collected, correspond to credit prices of over US$40/t$CO_2$eq (ICF 2010). Currently the voluntary carbon market offers 4.8 US$ /tCO_2eq which is far below this level. Thus additional financing is necessary, when this option is considered for ODS bank management.

Furthermore, the existing policy framework in some countries does not allow the export and import of ODS, even if it is intended for destruction (see chapter 4). When national legislation prohibits the export of ODS, these substances cannot be exported to other counties such as the US where ODS are destroyed for carbon offsetting.

Finally, financing ODS destruction via the voluntary carbon market, allows the GHG emitting industry to follow a business-as-usual scenario, i.e. to continue their historical emission pathway - justified by destroying ODS banks.

There is no strong incentive to reduce overall emissions, i.e. to invest in environmental friendly technology. Furthermore, those participating in the voluntary carbon market are interested in broader social benefits such as poverty reduction; emission reductions alone are often not enough motivation. This is different, when emissions reduction targets are mandatory. However, the emission limit has to be defined conservatively ensuring avoidance of perverse incentives.

The problem described above is intensified by the different time horizon of the climate impacts of ODS, HFC and CO_2. The lifetime of the most prominent ODS, CFC-12 is estimated to be around 50 years. Lifetimes of HCFC range from about 1 to 20 years. Their highest climate impact will therefore occur in the first half of this century. This is reflected by the much higher GWP-20 compared to the GWP-100, which is more commonly used. CO_2 on the other hand can remain in the atmosphere for several hundred years (Inman, 2008; Rogelj et al. 2014). Reducing ODS or HFCs (also referred to as short-lived climate forcers, SLCFs; cf. SAP 2014, Rogelj et al. 2014) with their high GWPs will mainly influence the near-term temperatures. Whilst the reduction of ODS and HFC is an important fast action measure to reach the global goal of limiting climate change to 2°C, it can only be a complementary measure and should not be cancelled out by higher CO_2 emissions. Permitting more CO_2 into the atmosphere now because of ODS or HFC reductions will keep negatively affecting the climate in the long run (Rogelj et al. 2014). The destruction of ODS under the voluntary carbon market is therefore no feasible instrument for climate protection as it does not ascertain the necessary reduction of both ODS and CO_2 emissions.

6 The engagement of ODS bank management in developing countries – status quo

The engagement in ODS management can be described as the activities that reduce emissions from ODS banks. Developed countries generally have a more advanced ODS bank management compared to developing countries (cf. ICF 2008a, 2010b; SKM ENVIROS 2012). The focus of this chapter is highlighting activities in the field of ODS bank management in developing countries.

Developing countries that want to tackle ODS bank management or enforce their existing management, have to consider three key questions, as indicated in Figure 11:
1) What is the amount of existing reachable ODS banks in the country and which subsectors are most important?
2) What activities have already been undertaken by the government in view of ODS bank management (important to identify gaps)?
3) Are there suitable preconditions in the country that might support ODS bank management?

Most often, developing countries lack ODS bank data, because the reporting requirements under the Montreal Protocol focus on consumption of ODS, not ODS banks. In case there is a lack of data, the establishment of an ODS bank inventory should be one of the first steps of the countries to start with (see part 1 of Figure 11). Global ODS bank data are only available on an aggregated basis, but not on the country level (see chapter 2.2).
Possible ways a country could be involved in ODS bank management are shown in part 2 of Figure 11 whilst part 3 shows suitable preconditions. Both will be highlighted in this chapter.

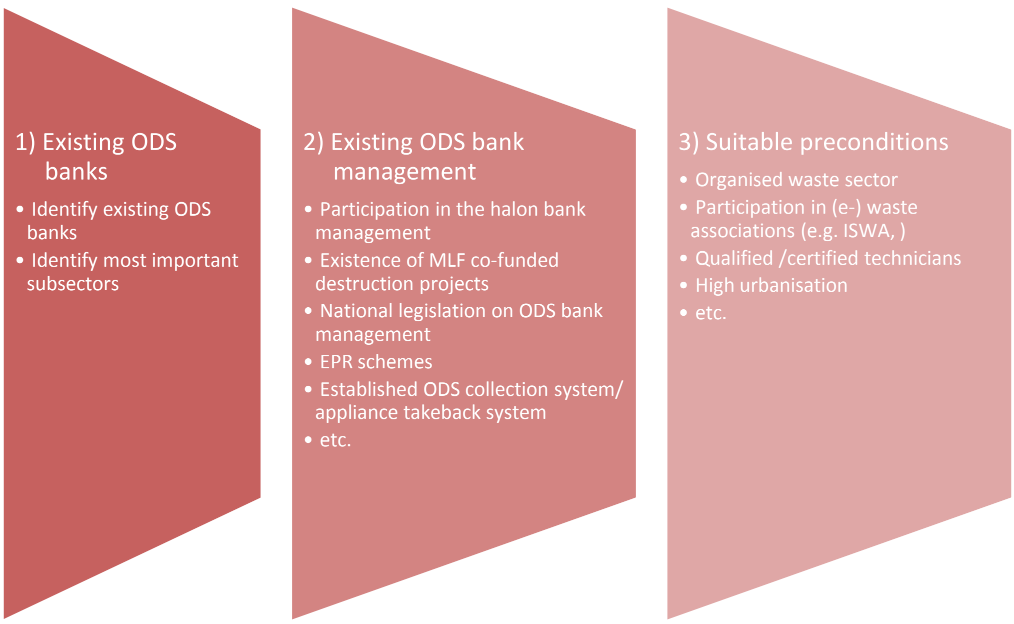

Figure 11: Three important components when establishing or enforcing ODS bank management

6.1 Existing ODS bank management

The current focus of many developing countries is clearly on phasing out the consumption and production of ODS under the commitments of the Montreal Protocol. In contrast, ODS bank management is still at its beginning in many developing countries. However, there are two important initiatives under the Montreal Protocol in the field of ODS bank management, after the significance of ODS banks with its associated emissions have been increasingly recognised: the halon bank management and the destruction demonstration projects.

6.1.1 Halon bank management

Several developing countries have established a halon bank management system (Figure 12). Halons are used as fire-fighting and explosion suppression agents and their main application is in aviation, the military and the oil and gas industry (see also chapter 1). Their production ceased in 1994 in developed countries and in 2010 in developing countries due to the commitments under the Montreal Protocol. Even though the decision for halon phase-out has been taken as early as 1992, at the Meeting of the Parties in Copenhagen, it was decided at the same time to allow unrestricted trade of recycled halons. This required planning for the recycling and reuse of halons. In order to implement this, the halon bank management was developed. Several countries participated, but the management systems are operating with varying success (Figure 12). Observed barriers have been a lack of information, financing, technology, logistics and a legal framework (see also chapter 4.)

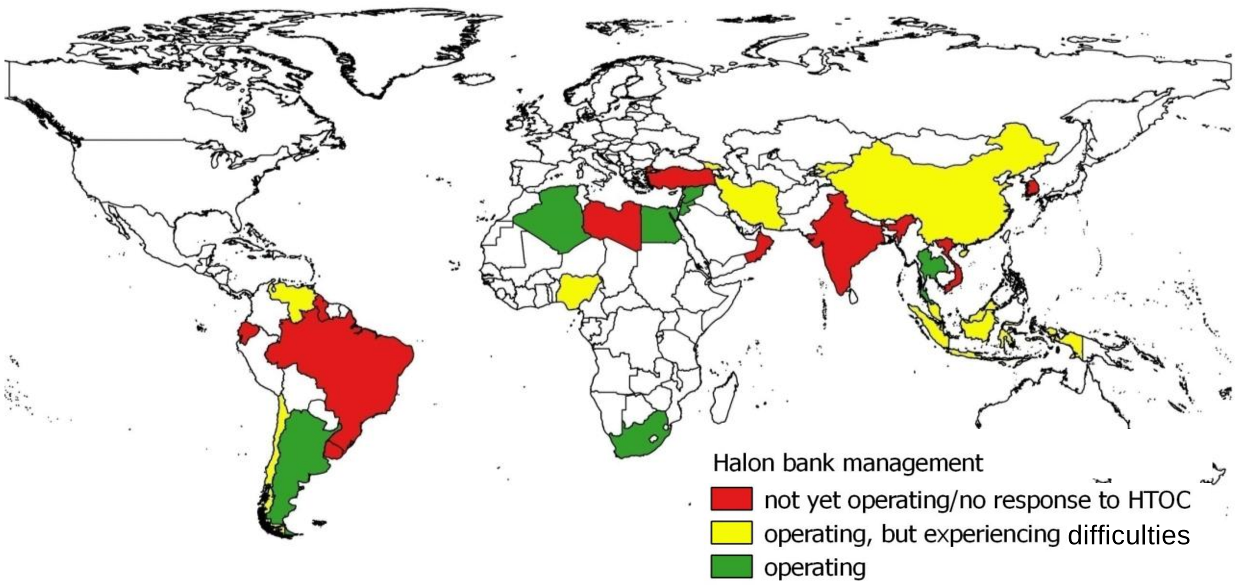

Figure 12: Developing countries that have established a halon bank management system. The colours indicate different levels of implementation success, according to HTOC (2010)

6.1.2 Demonstration projects for CFC and HCFC destruction

The Multilateral Fund decided[21] in 2009 to provide financial support for demonstration projects in several A5-countries. Developing countries that have demonstration projects for ODS destruction (mainly for CFC) are shown in Figure 13. The aims were firstly, to trigger the process of ODS bank management and secondly, to explore barriers and success factors in developing countries. The eligibility criteria under the MLF considered the countries' opportunities for storage, transport and destruction of ODS, with a focus on local cost coverage and overseas facilitation of destruction. Collection activities are explicitly not funded and virgin ODS stocks must be excluded from destruction. Regulatory assistance and best practice recovery, however, was not required in the guidelines but still addressed in some countries proposals.

[21] Decision 58/19

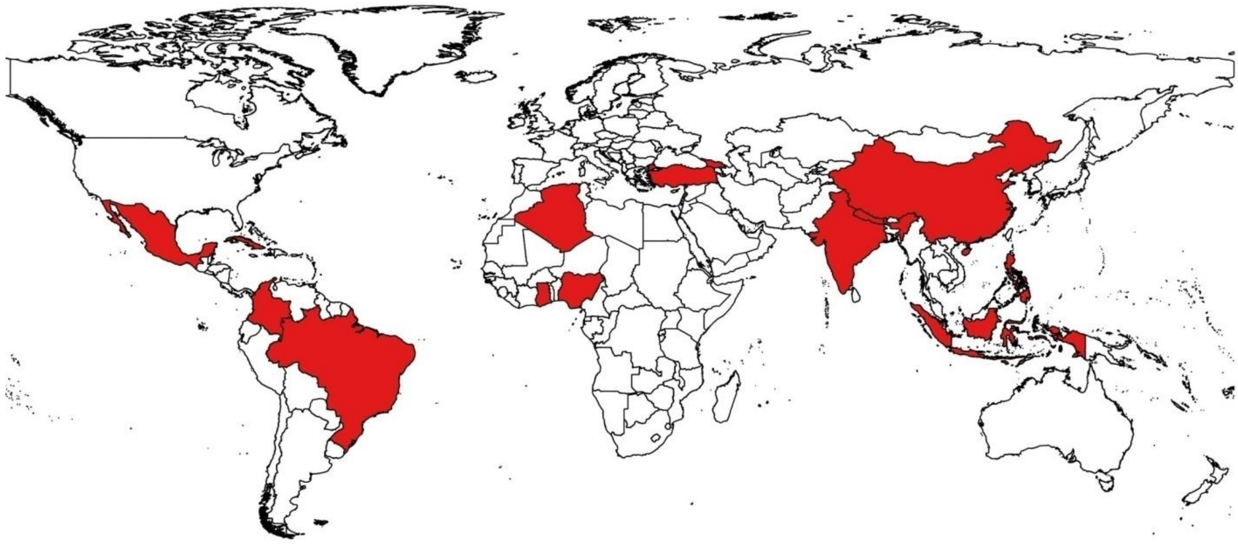

Figure 13: Developing countries that have demonstration projects for ODS destruction (UNEP/ExCom 2013)

An overview of approved projects including anticipated destruction technologies and long term financing plans is given in Table 9. In total, the MLF approved approx. 12 million US$ for 14 demonstration projects. Individual projects were funded with ca. 1 million US$ on average; China received the largest amount with 2.5 million US$. Cost effectiveness ranges between 4 US$/kg in Cuba to 26 US$/kg in Georgia. Local destruction is planned in five countries, achieving approximately 7 metric tonnes (Cuba) to 31 metric tonnes (Algeria) per facility and year. Other countries export their ODS to the US or Europe for final destruction in commercial destruction plants, partly aiming to receive carbon credits.

The summary in Table 9 shows that many countries rely on the voluntary carbon market to finance ODS bank management. However, this is related to some critical issues (see chapters 4 and 5). Furthermore, the carbon price has decreased significantly over the last few years and is currently at a low level of 4.9 US$/t CO_2eq (Forest Trends' Ecosystem Marketplace 2014). That is, many countries did not use the initial one-off MLF funding to introduce sustainable and sufficient national financing mechanisms under the demonstration destruction projects.

Unfortunately, the design of the projects under the MLF lack to provide important insights on how to:

- provide incentives for national regulation on producer responsibility
- avoid perverse incentives for destruction of non-compliant production of ODS
- provide incentives for the application of best available practice of dismantling
- achieve wide application for HCFCs, other ODS and HFCs

Further activities are strongly needed, to transfer best practice examples of ODS bank management to developing countries.

In summary, the projects under the MLF show good potential to demonstrate immediate action, which is especially valuable for small countries with no or very little infrastructure. For larger countries the projects appear insufficient to provide proper guidance on establishing national frameworks and capacities to follow long term effective strategies.

Table 9: Overview of existing ODS destruction demonstration projects, financially supported by the Multilateral Fund

Country	Destruction technology	Strategy	Long-term financing plan	Status	Cost effec-tiveness (US$/kg ODS)
Algeria	Cement kiln retrofit	Enforcement of existing ODS policies	Obtaining carbon credits after project finalization for funding of future activities	approved in 2014	10.23
Cuba	Rotary cement kiln and plasma decomposition (Japanese technology)	Establishing a logistic framework for the transport, storage and destruction of ODS in Cuba	Operating costs paid by the government	approved in 2011	3.95
Ghana	Export for destruction	Set up of a disposal center, where ODS is collected and sorted for either reclamation or destruction; GEF-funded refrigerator replacement scheme	Carbon credits to scale up	approved in 2011	22.4
China	Existing plasma arc technology and rotary kiln	Development of guidelines for standardized destruction routines for multiplication in other provinces	Local Environmental Protection Bureaus fund collection activities	approved in 2012	11.45
Nigeria	Export for destruction with EOS Climate to El Dorado/ USA	Carbon funds intended to be used to establish collection and recycling center for domestic appliances	Aims at becoming self sustainable via carbon financing	approved in 2012	10.91
Colombia	Adaption of three rotary kilns	National policy for waste electrical and electronic equipment (WEEE) and replacement scheme for domestic refrigerators	Extended Producer Responsibility Scheme	approved in 2012	10.48
Turkey	Export for destruction	Institutionalize existing recovery and collection systems	Use of carbon revenue for upscaling and to set up a destruction facility within Turkey	approved in 2012	10.37
Europe and Central Asia (ECA)	Export to EU for destruction (co-disposal with POPs)	Strengthen collection system, set up of incentive scheme for ODS recycling	Aim to reduce disposal cost when ODS is aggregated from three countries; long-term financial concept to be developed during the project	approved in 2013	12.45
Georgia	Export for destruction (co-disposal with POPs)	Strengthen national system of hazardous chemical management; inclusion of hazardous waste principles in national law	Development of financial national system during project	approved in 2013	25.9
Brazil	Test burns at two out of seven local hazardous waste management facilities	Establishment of an ODS waste management system that oversees the EPR/Waste Electrical and Electronic Equipment Programme	Extended Producer Responsibility (EPR) Scheme and revenues from recycled refrigerator material	approved in 2014	12.42

Country	Destruction technology	Strategy	Long-term financing plan	Status	Cost effec-tiveness (US$/kg ODS)
Mexico	Export to US for destruction	Ban on venting ODS; refrigerator replacement programme	Carbon credits, ERP schemes; defining responsibilities for financing recycling programmes	approved in 2011	9.13
Lebanon	Export to Europe for destruction	Enforcement of existing law requiring recovery, recycling, reclamation and destruction of ODS waste; establishment of aggregation facilities in Tripoli and Beirut	NI	approved in 2014	9.69
African countries (6 LVCs in Central Africa)	Technical assistance to develop methodology for LVCs to quantify stocks of unwanted ODS	Set up of a plan for systematic ODS waste handling	NA	approved in 2012	NA
Nepal	Technical assistance to export the ODS to US for destruction	Organisation of transport of ODS to the US via a broker (EOS climate)	NA	project completed (approved 2009)	NI

NA = not applicable
NI = no information provided

6.2 Suitable preconditions for ODS bank management in developing countries

There are environmental activities that are linked to ODS bank management. Thus it is recommended to consider aspects which could positively affect ODS bank management. As mentioned in chapter 5, there are higher chances for a successful ODS bank management, where commitments on proper waste management already exist. An infrastructure, the regulations for and the awareness of waste management or waste of electrical and electronic equipment (WEEE) are considered as optimal preconditions to extend the environmental engagement by including ODS in the waste management. The most comprehensive overview on solid waste management with regional and national information is provided by UNEP[22]. Further sources, databases and informative webpages dealing with waste management can be found in the Annex (Table 12). Waste projects in the context of development cooperation and the involvement of associations dealing with waste management can be used as an indicator for proactive waste management. Therefore, an overview is provided for GIZ solid waste projects in developing countries (Figure 14). Some of these projects include the informal sector and are found in the following countries:

[22] http://www.unep.org/ietc/Portals/136/SWM_Vol-II.pdf

- Tunesia
- Morocco
- Egypt
- Brasil
- Chile
- Uruguay
- Peru
- Philippines

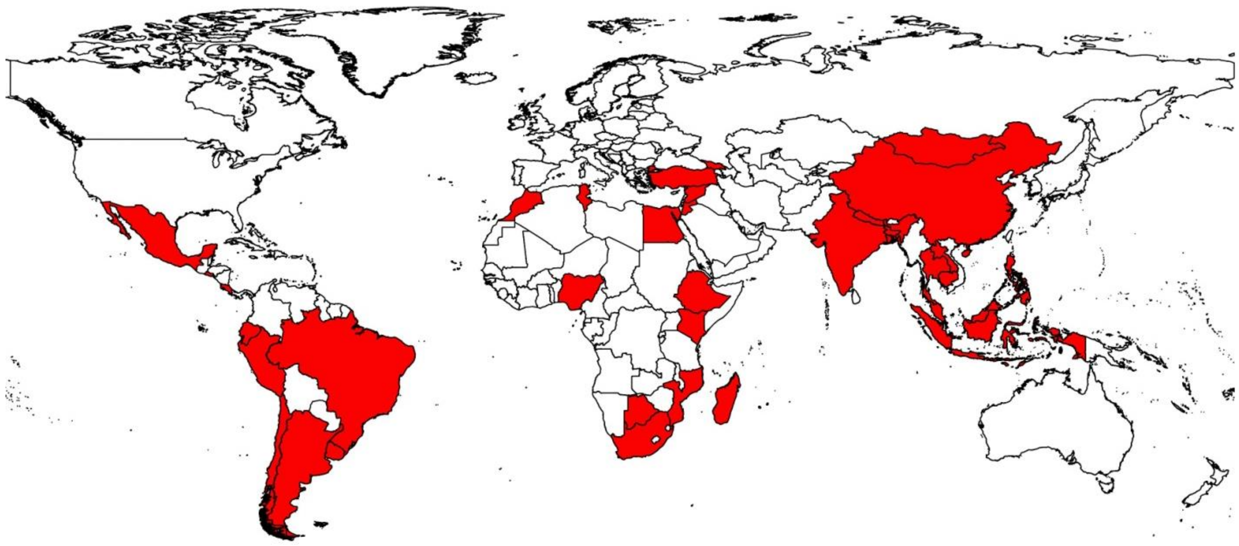

Figure 14: Developing countries where GIZ has been implementing waste projects.

Another important aspect which could facilitate ODS bank management are strong associations dealing with (e-) waste. Two of the most important international operating associations that promote and develop sustainable waste management worldwide are the International Solid Waste Association (ISWA, http://www.iswa.org/) and the SWEEP-NET (http://www.sweep-net.org/). The latter has a regional focus on the Mashreq and the Maghreb countries. Figure 15 gives an overview about participating developing countries.

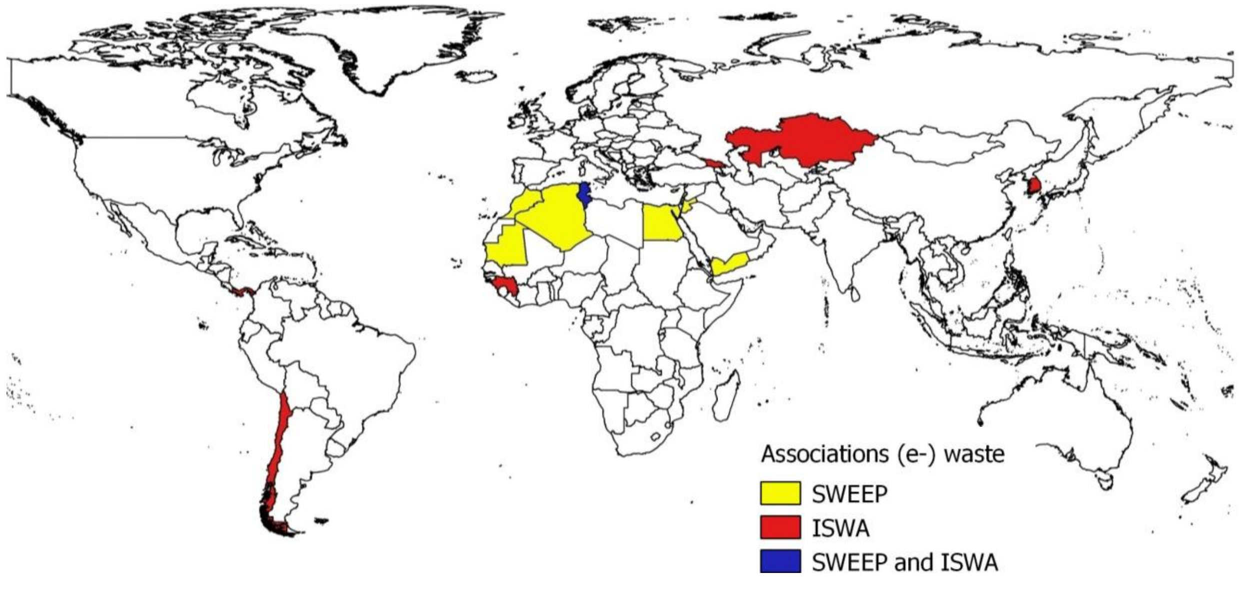

Figure 15: Developing countries that are members to associations dealing with (e-) waste: ISWA and SWEEP

Finally, the involvement in the fight against climate change, which is reflected by ambitious national climate goals, can be considered as a country`s willingness to reduce GHG emissions. Ambitious national climate goals can be seen as starting points for the establishment of ODS bank management systems. In these countries a strong collaboration between the climate and ozone unit is particularly important in order to harmonise visions and climate targets.

The national climate goals have been evaluated by the "Climate Action Tracker" (CAT) which is an independent science-based assessment[23]. Emission commitments and actions of various countries have been evaluated worldwide (Figure 16). Countries which are categorised as sufficient are: Bhutan, Costa Rica, Papua New Guiney and South Korea. The role model are the Maldives.

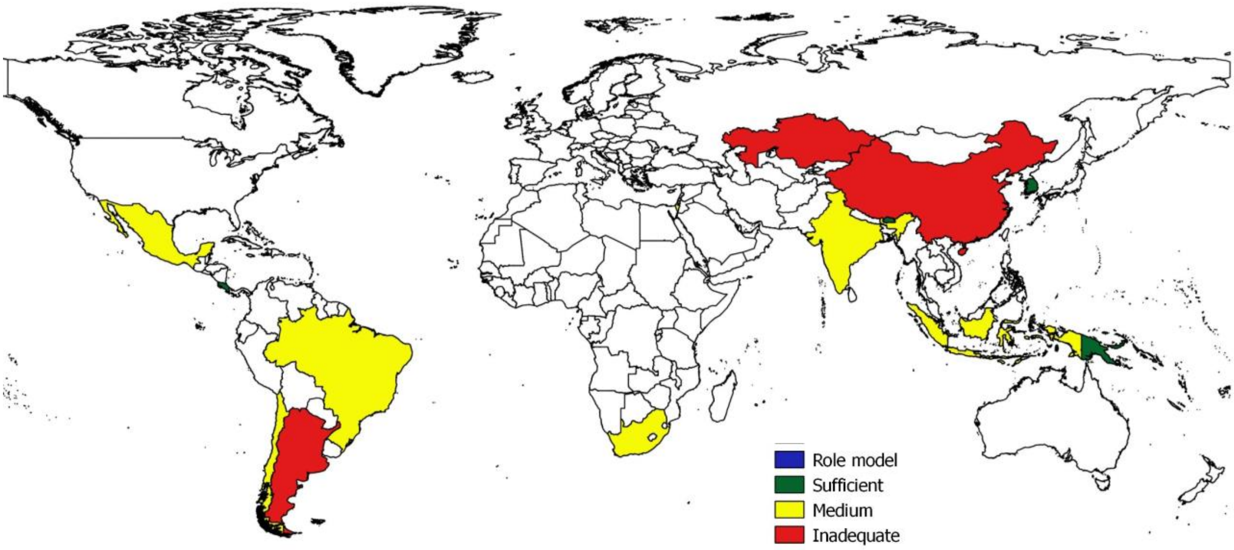

Figure 16: Developing countries and their varying engagement to fight climate change, based on the "Climate Action Tracker" (www.climateactiontracker.org)

[23] www.climateactiontracker.org

7 Conclusion

The Montreal Protocol has been effectively restricting the production and consumption of ODS. The activities under the Montreal Protocol have shown their effect: The ozone layer has not deteriorated further since 2000 and is believed to start recovering.

However, extensive use of ODS over the past decades have led to an accumulation of ODS banks. The management of these banks is not covered by the Montreal Protocol, but there has been an increasing awareness of the problems related to ODS banks since 2005, when TEAP published a first report on the extent of ODS banks: Emissions from ODS banks contribute significantly to climate change and the depletion of the ozone layer. Reducing these emissions by destroying ODS banks could accelerate the recovery of the ozone layer by 6.5 years. Fast reactions are however urgently needed because ODS are successively released from the banks.
The most important ODS are halons, CFCs, HCFCs and other halocarbons such as carbon tetrachloride and methyl chloroform. There are no significant banks for the latter and halons are intended for recycling and re-use. Consequently the most important substance groups are CFC and HCFC, predominately found in the refrigeration and air conditioning and foam sectors.

Initial efforts are being made in developing countries with respect to ODS bank management. Halon bank management was introduced from the beginning with the aim to reuse halons as long as possible. Other activities include demonstration projects for CFC and HCFC destruction in several developing countries, as decided by the Multilateral Fund in 2009. Still, ODS bank management is in its infancy in developing countries. The halon bank management is working with varying success only. The destruction demonstration projects appear insufficient to provide proper guidance on establishing national frameworks and to follow long term effective strategies.
Thus there is a strong need to quickly extend efforts in ODS bank management, avoiding negative environmental impacts. A successful ODS bank management needs a sound understanding of existing ODS banks, technical feasibility of ODS recovery and destruction, identification of associated costs as well as barriers and appropriate policy measures.

Reducing CFC emissions in the RAC and foam sectors result in the highest benefits for both the climate and the ozone layer. The largest CFC amounts (metric tonnes) are found in the commercial and domestic refrigeration subsector (refrigerants and blowing agents). As establishing an ODS bank management will not be substance specific, HCFC from the RAC sectors also will be covered, which is particularly important to fight climate change. HCFCs are dominantly found in the commercial refrigeration and stationary AC subsector.
Overall, the most important subsectors are the commercial and domestic refrigeration subsectors and the stationary air conditioning subsector and the appliances within these subsectors should be given preference for ODS bank management.

These subsectors can also be managed with comparably low effort regarding the technical feasibility and costs of ODS bank management. Because of relatively low costs, industrial refrigeration should be part of ODS bank management, even though little amounts are found in this subsector.
A significant part of CFC blowing agents (~ 50 %, metric tonnes) is found in construction foams used for buildings, but at the moment it requires high effort to recover ODS from these foams. Furthermore, ODS banks in construction foam are not diminishing as quickly as in RAC equipment due to long building lifetimes. Thus foam subsectors are currently not a priority for ODS bank management.

The most important barriers are informal, financial, technological, logistical, and legal barriers. To overcome these barriers, practical guidelines are needed which explain the barriers and provide solutions. Based on the barriers mentioned during the demonstration destruction projects, the guidelines should at least address the following points:

- How can ODS inventories be compiled in order to quantify ODS banks?
- How can the long-term ODS waste stream be assessed in order to effectively design and manage sufficient capacities for destruction?
- How to establish a sustainable financing scheme for ODS bank management?
- How to create appropriate incentives to motivate end-users and the informal sector to return ODS or ODS containing equipment? The main challenge being to avoid as much as possible a cost burden (disincentive) for either end-users or technicians.
- How to establish a business plan for ODS bank management, including all cost aspects, such as ODS storage, destruction and management?
- What are the options for destruction and required capacities and resources, e.g. training of technicians and operators, implications of retrofitting existing kilns etc.?
- What has to be considered under relevant chemical conventions, such as the Basel Convention in case of transboundary movement?
- Which regulations and enforcement structures are necessary for an effective ODS management?

In general a number of policy measures are required to establish ODS bank management. The most promising policy measures are regulations and enforcement, the development of technical standards and economic instruments to establish a sustainable financing mechanism e.g. through EPR schemes, as well as accompanying measures such as training and certification of technicians. The introduction of laws typically goes in parallel with educational measures such as technicians training, awareness raising and ideally mainstreaming environmental protection into government and civil society.

In developing countries where most banks are still not recovered, EPR schemes – particularly suitable for appliances – are generally preferable over financing schemes depending on the voluntary carbon market, because only EPR schemes provide a long term stable and sufficient incentive to invest in environmentally safe technology.

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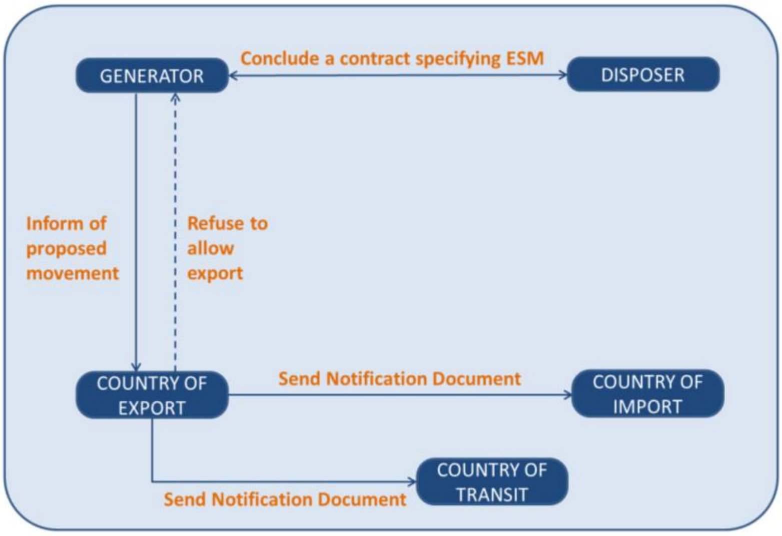
9 Annex

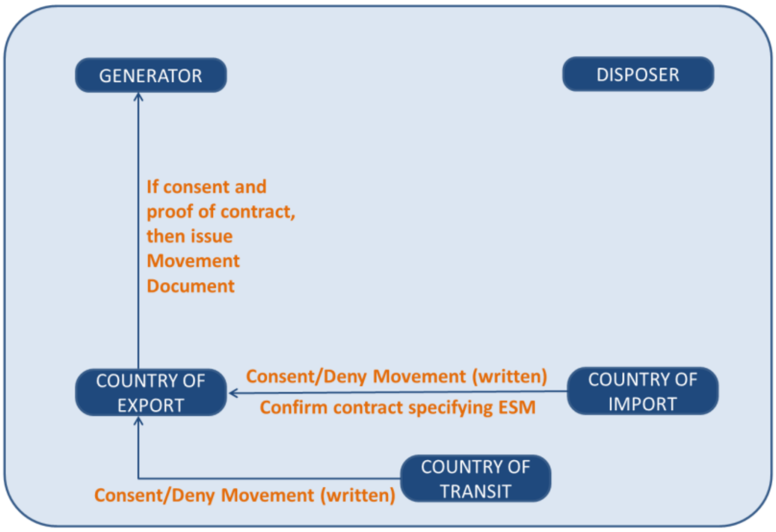
According to Article 6 of the Convention, any transboundary movements of hazardous and other wastes are subject to prior written notification from the exporting country and prior written consent from the importing and, if appropriate, transit countries. Extensive information has to be supplied by the exporting country (see tables below, Table 10 ff.). Parties are to prohibit the export of hazardous and other wastes if the country of import prohibits their import.
The Convention also requires that information regarding any proposed transboundary movement be provided using the accepted notification form, and that the approved consignment be accompanied by a movement document from the point where transboundary movement commences to the point of disposal.
The notification document is intended to provide the competent authorities of countries concerned with the information they need to assess the acceptability of the proposed waste movements.
The movement document is intended to travel with a consignment of waste at all times from the moment it leaves the waste generator to its arrival at a disposal or recovery facility in another country.
Finally, the document is to be used by the relevant disposal or recovery facility to certify that the waste has been received and that the recovery or disposal operation has been completed.
When transboundary movement of hazardous and other wastes for which consent has been given by the countries concerned cannot be completed, the country of export is to ensure that the wastes in question are taken back into the country of export for their disposal if alternative arrangements cannot be made. In the case of illegal traffic (as defined in Art. 9, paragraph 1), the country of export is to ensure that the wastes in question are taken back into the country of export for their disposal, or are disposed of in accordance with the provisions of the Convention.

The four stages of Prior Informed Consent procedure as described by the Basel Convention are pictured here (UNEP/SBC, 2011b):

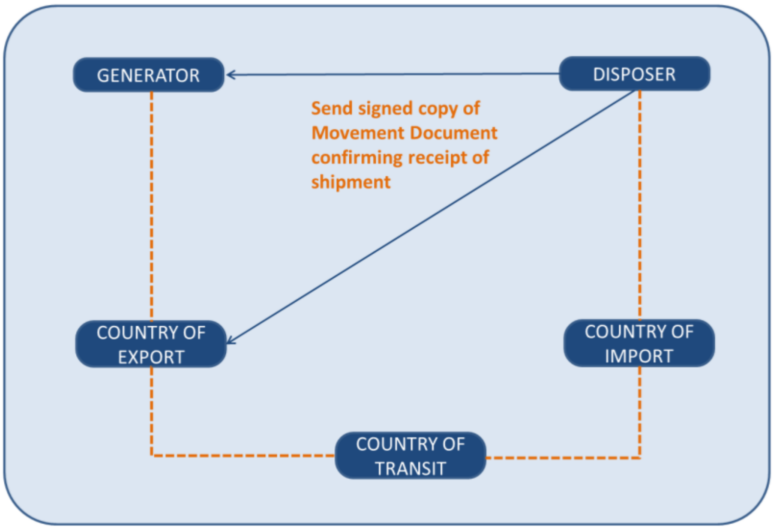
Stage 1: Notification



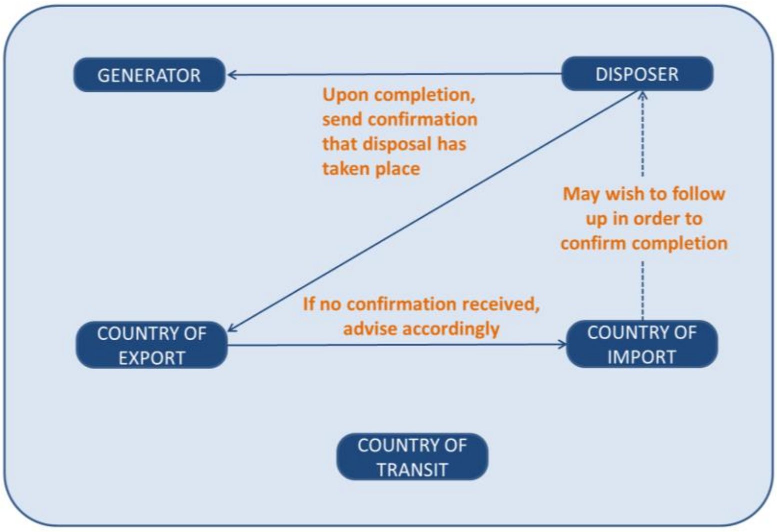
Stage 2: Consent & issuance of movement document



Stage 3: Transboundary movement



Stage 4: Confirmation of disposal



The tables below show the information reported under the Basel Convention in the case of transboundary movement:

Table 10: Information to be provided on notification of transboundary movement according to the Basel Convention

	INFORMATION TO BE PROVIDED ON NOTIFICATION	Notes
1.	Reason for waste export	
2.	Exporter of the waste	1/
3.	Generator(s) of the waste and site of generation	1/
4.	Disposer of the waste and actual site of disposal	1/
5.	Intended carrier(s) of the waste or their agents, if known	1/
6.	Country of export of the waste - Competent authority	2/
7.	Expected countries of transit - Competent authority	2/
8.	Country of import of the waste - Competent authority	2/
9.	General or single notification	
10.	Projected date(s) of shipment(s) and period of time over which waste is to be exported and proposed itinerary (including point of entry and exit)	3/
11.	Means of transport envisaged (road, rail, sea, air, inland waters)	
12.	Information relating to insurance	4/
13.	Designation and physical description of the waste including Y number and UN number and its composition 5/ and information on any special handling requirements including emergency provisions in case of accidents	5/
14.	Type of packaging envisaged (e.g. bulk, drummed, tanker)	
15.	Estimated quantity in weight/volume	6/
16.	Process by which the waste is generated	7/
17.	For wastes listed in Annex I, classifications from Annex III: hazardous characteristic, H number, and UN class	
18.	Method of disposal as per Annex IV	
19.	Declaration by the generator and exporter that the information is correct	
20.	Information transmitted (including technical description of the plant) to the exporter or generator from the disposer of the waste upon which the latter has based his assessment that there was no reason to believe that the wastes will not be managed in an environmentally sound manner in accordance with the laws and regulations of the country of import	
21.	Information concerning the contract between the exporter and disposer.	

Notes

1/ Full name and address, telephone, telex or telefax number and the name, address, telephone, telex or telefax number of the person to be contacted.

2/ Full name and address, telephone, telex or telefax number.

3/ In the case of a general notification covering several shipments, either the expected dates of each shipment or, if this is not known, the expected frequency of the shipments will be required.

4/ Information to be provided on relevant insurance requirements and how they are met by exporter, carrier and disposer.

5/ The nature and the concentration of the most hazardous components, in terms of toxicity and other dangers presented by the waste both in handling and in relation to the proposed disposal method.

6/ In the case of a general notification covering several shipments, both the estimated total quantity and the estimated quantities for each individual shipment will be required.

7/ Insofar as this is necessary to assess the hazard and determine the appropriateness of the proposed disposal operation.

Table 11: Information to be provided on the movement document according to the Basel Convention

	INFORMATION TO BE PROVIDED ON THE MOVEMENTDOCUMENT	Notes
1.	Exporter of the waste	1/
2.	Generator(s) of the waste and site of generation	1/
3.	Disposer of the waste and actual site of disposal	1/
4.	Carrier(s) of the waste or his agent(s)	1/
5.	Subject of general or single notification	
6.	The date the transboundary movement started and date(s) and signature on receipt by each person who takes charge of the waste	
7.	Means of transport (road, rail, inland waterway, sea, air) including countries of export, transit and import, also point of entry and exit where these have been designated	
8.	General description of the waste (physical state, proper UN shipping name and class, UN number, Y number and H number as applicable)	
9.	Information on special handling requirements including emergency provision in case of accidents	
10.	Type and number of packages	
11.	Quantity in weight/volume	
12.	Declaration by the generator or exporter that the information is correct	
13.	Declaration by the generator or exporter indicating no objection from the competent authorities of all States concerned which are Parties	
14.	Certification by disposer of receipt at designated disposal facility and indication of method of disposal and of the approximate date of disposal	

Notes

The information required on the movement document shall where possible be integrated in one document with that required under transport rules. Where this is not possible the information should complement rather than duplicate that required under the transport rules. The movement document shall carry instructions as to who is to provide information and fill-out any form.

1/ Full name and address, telephone, telex or telefax number and the name, address, telephone, telex or telefax number of the person to be contacted in case of emergency.

Table 12: Overview about data bases, webpages and documents dealing with solid waste management and e-waste.

Organization/Name	Web/Document	Type of Database	Content
ISWA – International Solid Waste Association	http://www.iswa.org	Comprehensive library on waste management, bibliography of about 3.000 titles	Documents, publications, presentations, links to webinars
ISWA – International Solid Waste Association	http://www.iswa.org	ISWA task force final report, online publication	Contains reports and status updates on various waste management projects around the world
Urban Waste Management	http://www.gdrc.org/uem/waste/waste.html	Website containing basic information on urban waste management, list of publications, articles, etc.	Documents and info sheets, web resources, organizations and institutions
Waste Management	http://www.sciencedirect.com/science/journal/0956053X	Open access online journal, accessible on science direct	Various articles on issues relating to waste management
Ideas for Development	www.ideas4development.org/en/	Website, subpage on waste	Only very few articles on waste management
Proparco	http://www.proparco.fr/lang/en/Accueil_PROPARCO/Publications-Proparco/secteur-prive-et-developpement/Les-derniers-numeros/Issue-15-waste	Website focused on development aid issues, not a database as such, online journal	One journal with publications on the challenges facing developing countries in waste management
Best Practices on Solid waste management of Nepalese cities	http://practicalaction.org/docs/region_nepal/solid-waste-management-best-practices-nepal.pdf	Overview over various waste management systems in Nepal	No global content. Specific for Nepalese cities
Know the Flow	http://www.knowtheflow.com/category/life-cycle-management-2/waste-management-life-cycle-management-2/	Website. Subpage on waste management	Not a database as such. No global overview or collected data. Publications on various waste management systems and projects.
CODWAP	http://www.codwap.hs-bremen.de/02%20Material/HANDBOOK-%20WM_in_DC-CODWAP.pdf	Handbook. Waste management in developing countries	

Organization/Name	Web/Document	Type of Database	Content
UNEP	http://www.unep.org/resourceefficiency/Policy/ResourceEfficientCities/FocusAreas/SolidWasteManagement/tabid/101668/Default.aspx	Solid Waste Management Subpage on UNEP website	Short list of informational material on solid waste management and challenges in developing countries
UNEP	http://www.unep.org/ietc/Portals/136/SWM_Vol-II.pdf	Publication on waste management	Regional overviews and informational sources

9.1 Tables

9.2 Figures

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