

**MONTREAL PROTOCOL  
ON SUBSTANCES THAT DEplete  
THE OZONE LAYER**



**UNEP**

**Technology and Economic Assessment Panel**

**TASK FORCE DECISION XX/7 – PHASE 2 REPORT**

**“ENVIRONMENTALLY SOUND MANAGEMENT OF BANKS  
OF OZONE-DEPLETING SUBSTANCES”**

**October 2009**



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On Substances that Deplete the Ozone Layer**

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The opinions expressed are those of the Panel and its Task Force and do not necessarily reflect the reviews of any sponsoring or supporting organisation.

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# 1 Executive Summary

After reviewing the outcome of the Interim (Phase 1) Report of the TEAP Task Force responding to the relevant requirements of Decision XX/7, the Parties provided further inputs to the work during a pre-OEWG workshop on the destruction of banks of Ozone Depleting Substances (ODS) in Geneva and also during the 29<sup>th</sup> Open-Ended Working Group Meeting itself. The output from that activity was a set of further requirements, which were elaborated as shown in the Annex to this Report.

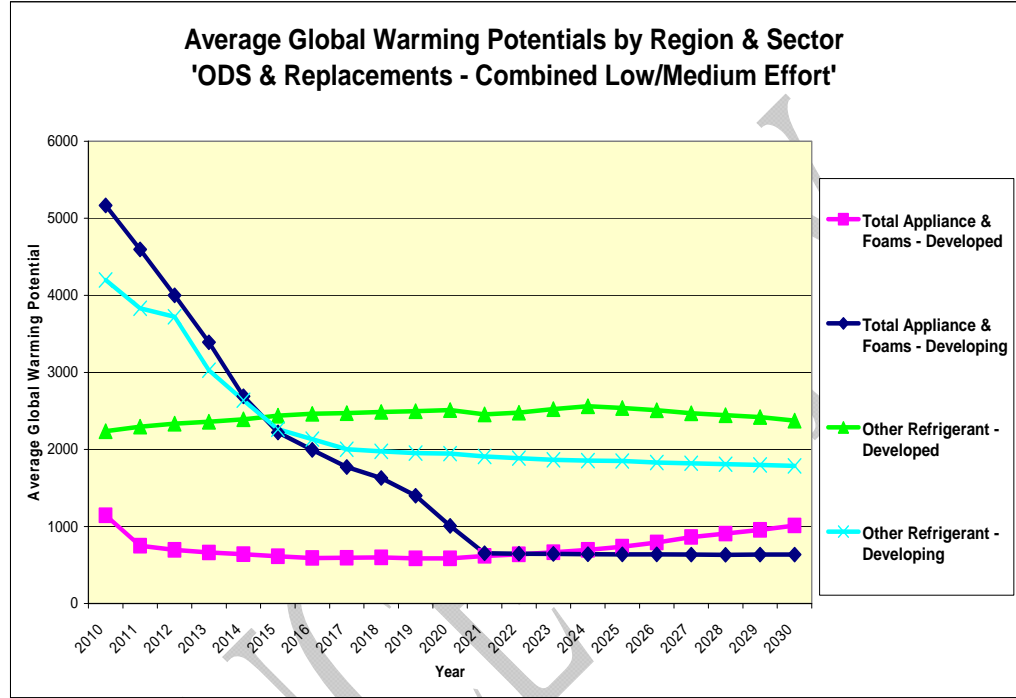
A number of points raised at the July 2009 Geneva meetings (e.g. the need for a time series of ODS flows into the waste stream) had already been recognised in the Phase 1 Report and were planned to be addressed in this second Phase. The Phase 2 Report has therefore covered the key themes listed below.

1. An evaluation of the flows of Ozone Depleting Substances (ODS) reaching the waste streams at regional (developed and developing country) level has been conducted. This has included a further evaluation of the levels of effort required to manage those flows. One of the major findings of this assessment has been that there are plentiful opportunities to manage low-effort banks within the next ten years.
2. In addition, a further elaboration of the ozone, climate and other environmental benefits arising from the management of these streams at end-of-life has been completed. Annual benefits in excess of 400 Mtonnes of CO<sub>2</sub>-eq will be achieved if low and medium effort banks reaching the waste stream are actively managed over the coming years.
3. A review of some sub-regional case studies has shed light on some of the challenges faced in planning management strategies and the potential value in addressing ODS synergistically with other waste issues. This includes matters such as enforcement of regulatory approaches and the importance of integrating ODS into wider waste management strategies wherever possible.
4. A more detailed review of costs and their timing has been achieved. In this Phase 2 Report, the Task Force has been able to evaluate the peak capacities required to manage the potential flows and also to assess the cost effectiveness, in climate terms, of taking these opportunities. A key driver in this instance is the average Global Warming Potential of the substance mix arriving into the waste streams.

Figure ES-1 illustrates that the decline of ODS in the mix of substances reaching the waste stream is likely to be offset in some sectors by the Global Warming Potential of the ODS replacements. This is particularly the case in the area of refrigerants, where the existing ODS replacements

(i.e. the ones that will reach the waste stream over the next 20 years) have an important climate forcing value.

**Figure ES-1: Trends in Average Global Warming Potentials by Waste Stream Source**



5 Although there is evidence to suggest that global destruction capacities could be sufficient to address the peak needs of ODS destruction, the logistical challenges have been reviewed in some depth. It is clear that efforts need to be made to minimise the transport elements during collection, prior to recovery, while a slightly less stringent policy might be operable for the transport of concentrated bulk ODSs for destruction provided that international shipment is not impeded by national or international legislation.

6 Since the discussions on future climate policy and, in particular, the future role of the carbon markets, are currently in flux, it has been possible to take advantage of this opportunity to explore future options for funding in a less constrained manner than might normally be the case. Much has happened in the intervening period between July 2009 and the finalisation of this Phase 2 Report, including the on-going development of ODS destruction Protocols and Methodologies. Of particular value has been the parallel work being conducted by the World Bank through ICF which has added particular focus to this Report’s discussions on the efficacy of the current carbon markets as a vehicle for funding ODS recovery and destruction. The Task Force concludes that it may be preferable to see

some form of buffer between the markets and the project activities but also recognises that the funding requirements are too great to be handled in the traditional grant-funded manner. Above all, this Phase 2 Report recognises that ‘the time is now’ because the ODS flows are already at their peak in terms of climate significance. The consequences of failure will be substantial in climate terms and the risks will have to be managed accordingly.

- 7 Finally, the Task Force has sought to recognise and address the important balance that needs to be maintained between recovery for re-use, reclaim and recycling – particularly in the refrigerant area. This Report concludes that there is not a universal hierarchy and that destruction can be the preferred option in one locality while recycling might be the preferred option in another.

In conclusion, in this Report the Task Force has taken the initial information presented in the Phase 1 Report and has elaborated it further in a number of ways. In reviewing the conclusions of the Phase 1 Report against the findings of this Report, nothing that was concluded at that time has been countermanded. Moreover, certain conclusions have now be refined in the light of the further analysis contained in this Report. The following specific conclusions are therefore drawn:

- The collection, recovery and destruction of refrigerants of all types represent the most immediate and cost-effective method of mitigating climate impacts from the release of ODS Banks.
- Developing countries offer particularly valuable opportunities over the next 10-15 years during which the CFC proportion remains significant in the refrigerant waste streams. The on-going prevalence of HCFC-22 in these waste streams will also maintain a significant climate return over the period up to 2030.
- For developed countries, the opportunity for end-of-life management of ODS-containing refrigerants will broadly be over by 2025. However, the management of the ODS Substitutes at end-of-life, many of which contain HFCs, will provide an on-going climate benefit from any infra-structures created to manage ODSs.
- The global flow of ODSs into the waste stream is expected to peak at 200,000-225,000 tonnes annually within the period 2018-2020 with over 90% of this amount being refrigerant. Although estimates of ODS destruction capacity are still preliminary, it is not anticipated that additional global capacity will be required, even if the level of activity in ODS bank management increases substantially. Nevertheless, there will

be significant logistic challenges in delivering recovered ODS to appropriate destruction facilities.

- Decisions to include ODS Substitutes within the scope of end-of-life activities could increase the demand for destruction capacity to as much as 400,000-450,000 tonnes annually by 2030, although some segregation and de-selection might be expected for those ODS Substitutes seen as relatively benign.
- Most refrigerant management plans implemented under the Montreal Protocol are focused on recovery to reclaim and recycle. As demand for servicing needs reduces in the period after 2015, active consideration needs to be given to the destruction of materials arising in this cycle. However, premature destruction which might stimulate re-manufacture must be avoided.
- Several protocols and methodologies are emerging within the voluntary carbon market community, the most notable of which are driven by the Voluntary Carbon Standard (VCS) and the Climate Action Reserve (CAR). Both take a conservative view on the substances which should be included to avoid perverse incentives and take due care of accounting for ODS replacements.
- Early retirement of refrigeration equipment could be justified on the basis of improvements in energy efficiency. However, early retirement in order to manage the ODS banks could be counter-productive if the replacement technologies offer no additional benefit in life cycle climate performance.
- The holistic management of domestic appliances has been practiced in both Europe and Japan for several years. The overall cost of the process in climate terms remains below US\$ 50 per tonne of CO<sub>2</sub> saved while significant quantities of CFCs persist in the waste stream but the situation will deteriorate thereafter.
- In developing countries, the CFC component in the domestic refrigerator stream will continue until at least 2020 but investment costs for the fully automated recovery and destruction of all ODS may not be supportable in all cases. Newer semi-automated refrigerator recycling plants may reduce the investment burden to some degree, but it is expected that many developing country regions will be obliged to focus exclusively on refrigerant extraction (Stage 1) processes.
- The potential for the funding of ODS Bank management activities continues to receive significant attention and a number of ideas are continuing to mature. There remains concern that unfettered use of the

voluntary carbon markets could strip out the low hanging fruit from the ODS banks and leave the more challenging areas unaddressed.

- The overall scale of the funding task also remains a significant and imminent challenge, particularly since ODS waste streams in the low and medium effort categories are currently at their peak. Linkage to wider climate programmes seems an inevitable step if the funding requirements are going to be substantively met.
- Insulating foams will be a minor source of ODS in the waste stream in the period to 2030. Current costs of recovery and destruction suggest that such projects will not be justified based solely on climate investment criteria. The combining of ODS flows (e.g. as with refrigerants and blowing agents in domestic refrigerators) may be an appropriate means of optimising foam bank management.
- Halons are unlikely to be included in near-term ODS destruction strategies and indeed the draft Climate Action Reserve standard excludes them from scope. This places further emphasis on the need to manage long-term stocks carefully to avoid unnecessary releases.



## 2 Linkage of the Phase 2 with the Phase 1 (Interim) Report

### 2.1 Development of the Phase 1 (Interim) Report

The Phase 1 (Interim) Report drew on a number of key sources in order to assess the overall potential for ODS bank management. These included:

- *Task Force on Destruction Technologies* (2002 & updates)
- *Task Force on Collection, Recovery & Storage* (2002)
- *Task Force Report on Foam End-of-Life* (2005)
- *IPPC/TEAP Special Report on Ozone & Climate* (2005)
- *TEAP Supplementary Report to the SROC* (2005)
- *Experts Workshop & Report (ExCom 48/42)* (2006)
- *ICF – Collection and treatment of unwanted ODS* (2007)
- *TEAP TF Response Report to Decision XVIII-12* (2007)

The Report was able to evaluate the source data and combine it in such a way as to produce an initial quantification of the reachable banks by level of effort required to manage them. It used the year 2010 as the reference year for which the size of ODS banks and costs of bank management were calculated. The following Table 2-1 is extracted from the Executive Summary of the Phase 1 Report.

**Table 2-1: Reachable ODS Banks with Different Levels of Efforts Reflecting the Ease of Access**

<i>Region</i>	<i>ODS type</i>	<i>Low Effort</i>	<i>Medium Effort</i>	<i>High Effort</i>
<i>(all in ktonnes)</i>				
Developed Countries	CFCs	123.82	239.76	1009.08
	HCFCs	631.86	308.23	838.73
	Halons	44.32	15.00	-
Developing Countries	CFCs	160.79	225.80	154.27
	HCFCs	563.49	645.72	347.22
	Halons	22.24	28.95	-
<b>Global</b>		<b>1546.52</b>	<b>1463.46</b>	<b>2349.30</b>

The Phase 1 Report was also able to make an initial assessment of the overall cost of bank management by region (Developed and Developing Countries). This assessment stopped short of dealing with high effort banks since it was recognized that technical feasibility of recovering such banks might still be marginal and therefore costs would be difficult to quantify.

Table 2-2 provides an overview of those cost estimates and highlights that ODS bank management, even for low effort banks, is likely to a much more expensive activity than previous tackled under the Montreal Protocol.

**Table 2-2: Summary of Bank Management Costs by Region and Effort**

<i>Region</i>	<i>Low Effort</i>	<i>Medium Effort</i>	<i>Total</i>
<i>(US\$ billion)</i>			
Developed Countries	15.96 - 26.21	45.23 – 59.37	61.19 - 85.58
Developing Countries	26.56 - 35.38	43.87 – 58.02	70.43 - 93.40
<b>Global</b>	<b>42.52 - 61.59</b>	<b>89.10 - 117.39</b>	<b>131.62 - 178.98</b>

From these initial evaluations, the following interim conclusions were reached.

- *An assessment of reachable banks through a further analysis of ‘levels of effort’ has provided a workable framework for presenting results based on reference to population density centred around the urban/rural divide.*
- *The cost of ODS bank management is linked fundamentally to the nature of each sector as well as the ‘levels of effort’ required.*
- *The climate benefit associated with ODS bank management measures has the potential to fund the bulk of the costs associated with process through direct and/or indirect carbon financing – possibly on a programmatic basis.*
- *Programmes are likely to be organised on a sectoral basis and the Task Force sees little or no opportunity to preferentially recover and destroy specific substance types.*
- *The ‘Low Effort’ banks would ultimately require a carbon price of approximately US\$ 15 per tonne of CO<sub>2</sub> saved to ensure their effective management based on the average global warming potentials.*
- *The ‘Medium Effort’ banks would ultimately require a carbon price in excess of US\$ 35 per tonne of CO<sub>2</sub> saved to ensure their effective management based on the average global warming potentials.*
- *There is a real risk that uncontrolled early action in the carbon market, without first establishing a working registry and methodologies, could undermine efforts to secure higher carbon prices in future.*
- *There is substantial concern that banks requiring retention for later use (e.g. halons) may be amongst the most lucrative to exploit in the short-term. Accordingly, some form of permitting scheme may be essential to ensure that only those elements of the bank that are truly surplus to requirements are eligible for funding. These issues will be explored further in the Final Report following further inputs from stakeholders.*
- *A number of other policy issues have been reviewed including the potential for perverse incentives such as production for destruction. However, the Task Force has concluded that suitable safeguards can be enacted to avoid malpractice, although particular care may be necessary in managing on-going production of ODSs for feedstock purposes.*



- *Destruction projects should be limited to those technologies recommended by Parties to the Protocol (as listed in section 3.1 of the 2006 Montreal Protocol Handbook), that are properly permitted according to government requirements.*
- *Destruction projects involving ODS imports must adhere to the licensing provisions established under agreement with the Protocol, and care should be given to make certain that international treaties concerning the trans-boundary shipment of waste are respected.*

However three key caveats were also identified in the summary of the outputs of the Phase 1 Report. These were that:

- *No overview has yet been given to the timing of the availability of banks, taking into consideration the lifecycle of products and applications and the influence that this might have on the infra-structure required for bank management.*
- *There has been no discussion of the institutional structures required to facilitate this additional level of project activity*
- *The regional analysis of the ODS banks has been limited to the divide between developed and developing country territories. Although data exists at sub-regional level, there is a concern within the Task Force that the level of additional analysis required would be too great to be presented in such a report format. One option for the [Final] Phase 2 Report might be to select one or more regional examples.*

This Phase 2 Report seeks to address these gaps in the coverage of the Phase 1 Report, as well as responding to a number of other items that were raised during a process that began at an ODS Workshop immediately prior to 29<sup>th</sup> OEWG in Geneva in July 2009 and continued into the OEWG Meeting itself. This process is described in the next section.

## **2.2 ODS Destruction Workshop and Follow-up Discussions at the 29<sup>th</sup> OEWG**

A Workshop to discuss the outputs of the Phase 1 Report was convened on Monday 13 July 2009 in Geneva and was attended by a wide-range of country representatives and other delegates. The day was structured to allow the presentation of the Phase 1 Report in a series of segments during the morning session. It also allowed for questions of general interest to be raised with the Task Force during the following period. The afternoon session was reserved for a presentation from the Ozone Secretariat on potential Funding Mechanisms and also for further discussions.

The co-chairs of the Workshop from Australia and Georgia were requested to summarise the outputs from the Workshop and to carry these messages forward to the OEWG-29 where they were reported. This led to the formation of a Contact

Group, which they also co-chaired in order to take forward the major themes and ensure that they were embodied into a draft paper carrying instruction to the TEAP for items to be considered, to the extent possible, within the Phase 2 Report. Annex 1 of this Report carries the text of that instruction, which is a copy of Annex B to the OEWG meeting report.

Although it was recognised that the instruction was structured as something of a ‘wish-list’, the TEAP and its Task Force has set about addressing all of the issues raised. However, recognising the constraints of the time available, the resources at its disposal and the lack of information in some instances, the TEAP would wish to confirm that this Phase 2 Report represents its ‘best efforts’ at this stage and will certainly require further updating in the following months to provide Parties with the best available information on which to act.

### 2.3 Responding to the Additional Requests and Development of the Phase 2 Report

TEAP has maintained its XX/7 Task Force to assist in the reporting of these issues. The membership of this Task Force continues as follows:

<i>Member</i>	<i>Affiliation</i>
<i>Paul Ashford (co-chair)</i>	<i>TEAP, co-chair FTOC</i>
<i>Julius Banks</i>	<i>RTOC</i>
<i>Christoph Becker</i>	<i>RAL Institute</i>
<i>Kristian Bruning</i>	<i>Climate Wedge</i>
<i>Michael Dunham</i>	<i>JACO Environmental</i>
<i>Lambert Kuijpers (co-chair)</i>	<i>TEAP co-chair, RTOC co-chair</i>
<i>Koichi Mizuno</i>	<i>CTOC</i>
<i>Miguel Quintero</i>	<i>TEAP, co-chair FTOC</i>
<i>Dan Verdonik</i>	<i>TEAP, co-chair HTOC</i>
<i>Paulo Vodianitskaia (co-chair)</i>	<i>RTOC</i>

In addition, the TEAP would also like to take the opportunity here to recognise the large contribution of the staff at Ecole des Mines (Armines) in France, via Denis Clodic and Stephanie Barrault, who have further assisted the Task Force by providing updated information on the time series of refrigeration equipment entering the waste stream at regional [and sub-regional] level. The assistance of World Bank and its consultant ICF is also recognised in exchanging information on a regular basis to assist in the development of a full picture of the current ODS waste management landscape.

It will already be clear from this section that the Task Force does not see this Report as a finalisation of the Interim Report prepared in June 2009, since it will not seek to repeat, in a more finalised fashion, the same material as was contained in the previous Report. Rather, the approach taken has been to treat both Reports as stand-alone documents and to title them as Phase 1 and Phase 2 of the same

overall submission to the Parties. This approach was already emerging at the time of the OEWG-29 and was broadly accepted as the most pragmatic approach to the subject by those consulted on the matter.

The main subjects covered in this Phase 2 Report are as follows:

- Development of a time series of ODS entering the waste stream by region
- A further review of the benefits arising from ODS Bank Management in terms of ozone, climate, other environmental and social factors, as well as economic factors
- Sub-regional examples of ODS Banks entering the waste stream
- Issues relating to the amount of investment required to manage the banks and its likely timing
- Logistical challenges arising from efforts to manage the banks
- Funding sources and factors affecting the availability of funds
- Ensuring that decision-making is carried out on an environmentally sound basis

The following sections address these items sequentially.



### **3 ODS Reaching the Waste Stream by Region**

#### **3.1 Substance Mix (Developed and Developing Countries)**

The Phase 1 Report primarily addressed the challenges arising from ODS Bank Management in its totality and did not specifically seek to iterate the time-related elements in a systematic way. In practice, the international community will need to evaluate the efficacy of addressing the ODS Bank agenda, not only in the context of the total costs and benefits, but also with a full understanding about when those costs and benefits will be incurred. This requires a clear understanding of the likely flow of ODS into the waste stream, which in turn requires a systematic understanding of the stock of installed equipment and products containing ODS.

The factors influencing emergence of ODS into the waste stream are as follows:

- The year of manufacture of the specific equipment or product containing the ODS
- The quantity of ODS contained in the equipment/product in question
- The anticipated equipment/product lifetime
- The likelihood of the ODS reaching the waste stream

The first three of these can be assessed with some degree of accuracy, although it is recognised that individual equipment/product lifetimes will not be precise, but will be statistically spread around an average (mean) value. The models used historically by TEAP in its reports on banks have been based on knowing these three parameters. One of the particular advantages of such an approach is that it allows the bottom-up historic estimate of consumption to be aggregated according to the year of manufacture and then compared with independently gathered information on sales of ODS to the market. This cross-check allows for a high level of confidence in the overall age-profile of the banks in question. It also enables re-forecasts to be made if information on the average lifetime of a particular product or equipment type is reassessed over time. This vintaging approach is common in a number of the major emissions forecasting models.

In order to determine the mix of substances destined to reach the waste stream in a given year, these vintaging models can be interrogated to see how many pieces of equipment or specific products are scheduled to be decommissioned in that year. This can be done both regionally and sub-regionally depending on the sophistication of the model. However, it is important that when comparing different models (e.g. at country level) that some check is made to ensure that the methodologies are consistent. One of the challenges for country-level vintaging models is that the corroborating data on historic ODS consumption is harder to

identify at equipment/product level, since the UNEP reporting requirements under Article 7 do not stipulate the need to separate consumption by use sector.

An alternative way to assess the mix of substances arriving in the waste stream in a given year is by carrying out a survey of products and equipment decommissioned in that year. Where end-of-life management schemes are already well established (e.g. in refrigerator recycling in Europe and Japan) a cross sectional sample of ODS reaching the waste stream can be taken. However, the challenge in this instance is to recognise that the fourth factor in the list comes into play – namely *the likelihood of the ODS reaching the waste stream*. Where schemes can be guaranteed to be 100% effective, it can be expected that the survey sample should completely reflect the substance mix predicted by the vintaging approach. However, this is not always the case and knowing the level of recovery taking place is not always as easy as it might seem.

There are other reasons why the substance mix predicted by a vintaging model and that observed in a survey might not agree. Such a circumstance could arise, for example, if the average assumed lifetime for a specific product or type of equipment were either significantly too long or too short. An assumption that was too long would create an over-estimate of the amount of CFC reaching the waste stream in a given year, while an assumption that is too short will lead to an under-estimate. Therefore, while one such approach can provide support to the other, neither stands the test of validity in isolation.

Notwithstanding this, the vintaging model has a specific advantage that cannot be met by the surveying method – namely that it can be used to forecast the future trends in substance mix based on historic information on consumption. This is not an option open to the survey method, since there is no basis for extrapolation. Some reported approaches have used linear trends as a proxy for the annual change in substance mix reaching the waste stream. However, the Task Force is dubious about such an approach, since many technology transitions (e.g. from CFCs to HCFCs) have taken place in relatively short periods, often driven by regulatory phase-out dates. The impact of this discussion is dealt with further in Section 3.3.

A further factor influencing the composition of a substance mix could be a decision to directly intervene in the ‘natural’ product lifecycle. This can happen when early retirement programmes are introduced for reasons either related to ODS management itself or, perhaps, through wider energy efficiency programmes. In such circumstances, the lifetime of a product or equipment can be artificially shortened. One of the implications of taking such action is that recovery in the year in question will be boosted, but that there will be a corresponding dip in recovery in later years. Such action might still be justified if the product or equipment continues to lose ODS during its normal lifecycle (as is typical for refrigeration equipment) but may be less appropriate if the action of

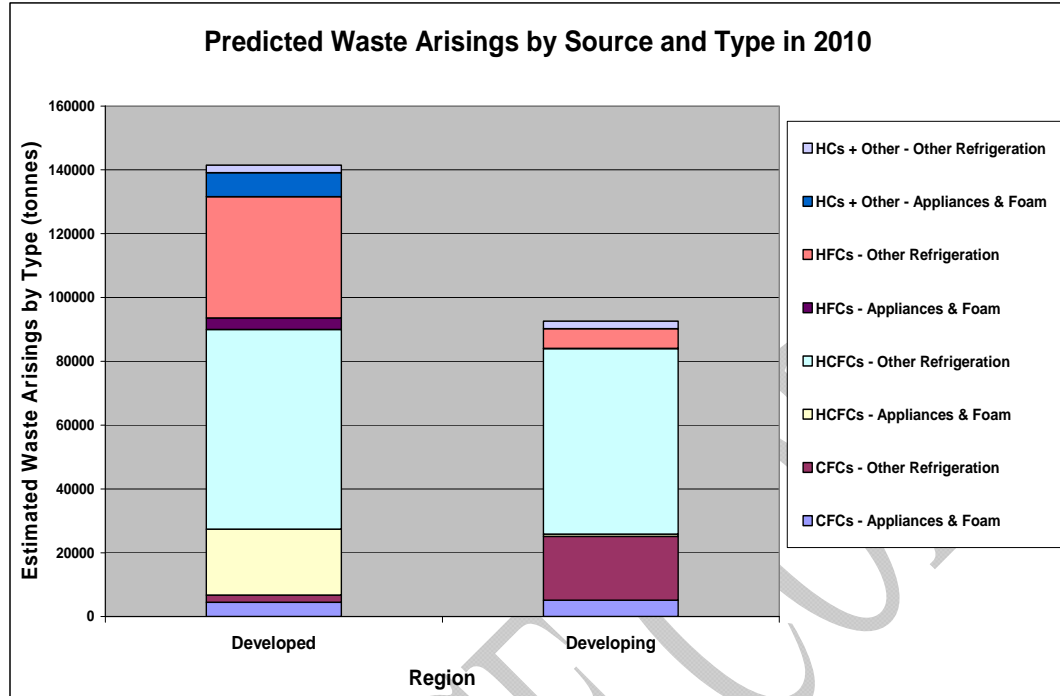
making a dedicated intervention merely promotes release that would otherwise not have happened.

Although all of these caveats need to be borne in mind, the Task Force has taken the clear view that a vintaging model approach is the most appropriate for the purposes of this Phase 2 Report. This is particularly the case, since the Report is asked to address the future time-series beyond 2010 (where the Phase 1 Report looked at all the amounts in products and equipment that were assumed to reach the waste stream in some future year). Where appropriate other survey observations are also taken into account, but only to inform, and potentially revise, the assumptions made in the vintaging model approach. The assessments of substance mix that follow are therefore based on the assumption that all ODS being decommissioned in a year have the potential to reach the waste stream (i.e. likelihood of 100% recovery) even though it is clear that fugitive releases and decisions not to recover will reduce the level of recovery in practice.

The following graph compares the substance mixes arriving at the waste streams within both developed and developing countries in 2010. The outputs are influenced by a number of factors including:

- The later transition from CFCs to HCFCs and other alternatives in developing countries
- The dominance of non-domestic appliance refrigerants in the waste arisings
- The impact of the shorter lifecycle of refrigeration equipment when compared to insulating foam used in buildings

Figure 3-1: Predicted Waste Arisings in 2010 by Region



### 3.2 Specific Considerations for Halons

For fire suppression equipment typically containing halons, the concept of end-of-life is rather different. In practice, the halon can continue within its own recycling loop ‘in perpetuity’ unless there is a specific intervention to release or destroy it. The only routine fugitive losses arising from the sector are those associated with testing. Only when the halon becomes sufficiently contaminated is there a real case for taking the material out of circulation and destroying it.

In recognition of these facts, a whole industry has emerged on the sound management of halon banks. Such practices are often occurring where individual organisations are keen to identify and protect supplies for future use. In other instances, exchanges have been set up to match supply and demand. This has often required the need for adequate long-term storage provisions and this matter is covered further in Section 6.6.7.

For these reasons, halons have not been included in the basic substance mix assessment carried out in this Section.

### 3.3 Time Series of ODS and ODS Substitutes Reaching the Waste Stream

Section 3.1 has already highlighted the relevance of adopting a vintaging model approach to derive a reliable assessment of likely trends in ODS flows reaching the waste stream. This approach therefore underpins the paragraphs that follow.



Bearing in mind the range of products and equipment in which ODS are currently contained, the timing of their respective manufacture and their differing lifetimes, it is clear that predicting the arrivals in the waste stream is a challenging and complex process. In order to simplify the analysis, and as already shown in Figure 3-1, this Report deals with the waste arisings from blowing agents and refrigerants in two major categories:

- Arisings from “Domestic Appliances (refrigerant and foam) and Foams”
- Arisings from the decommissioning of “Other Refrigerants”

The inclusion of refrigerants from domestic appliances in the first category reflects the fact that the recovery and destruction of these usually be associated with the wider management of the appliance. In the other sectors using refrigerant, there is more likely to be recovery from equipment in situ. This demarcation therefore become particularly helpful later in the report when considering ODS recovery and management strategies.

A further basis of analysis has been to consider ODSs in isolation and then together with all ODS substitutes. This is important when the recovery and destruction of ODS substitutes might be an appropriate additional environmental goal (e.g. with HFCs).

The third basis of primary analysis is by region, where region is defined, as in the Phase 1 Report, in the context of developed and developing country quantification. In addition, Section 5 provides some specific sub-regional perspectives.

The final basis of primary analysis (*making 16 permutations in all!*) is according to ‘level of effort’. Most attention is applied to ‘low’ and ‘medium’ effort categories, as in the Phase 1 Report, reflecting the fact that these are the most likely to be managed. However, the two scenarios assessed are:

- Low effort banks managed in isolation
- Low and medium effort banks managed together.

It is understandably assumed that medium effort banks would not be managed in isolation and this assessment is therefore not considered separately.

Within this section, the analysis is conducted in metric tonnes of ODS and ODS substitutes arising. The specific metric tonne value is an important figure to assess by region and sub-region since it defines the capacity required to manage the flows. Section 3.4 evaluates in greater detail the potential environmental benefits that may be available, either in terms of climate benefit or in terms of ozone depletion avoidance.

The expectation is that most regions will experience a flow of ODS which could last for 30 years or more. This has advantages in that it limits the amount of annual capacity required to manage the banks and even allows the ability to stockpile amounts from year-to-year if there are abrupt peaks in supply to the waste stream. This, of course, assumes that the product/equipment is of a type, which allows such stockpiling to occur.

The drawback to such elongated management periods is that infrastructures need to be installed and maintained on a long-term basis. Additionally, the peak ODS flow might not be sufficient to support an investment in the first instance and might therefore limit the geographic spread of destruction facilities that can be justified. For this reason, it becomes particularly important to identify synergies with destruction facilities installed for other purposes. This aspect is discussed further in Section 6.6.

A further time-related factor is the variation source of ODS with time and, particularly, the inter-relationship between low and medium effort sources. It is often assumed that the low effort sources will emerge first, but this is not always the case. Table 3-1 overleaf is reproduced from the Phase 1 Report as a reminder of the low, medium and high level categories as defined at that time according to population density (urban/rural).

**Table 3-1: Impact of Population Density on Effort Required to Manage Banks**

<i>Sector</i>	<i>Low Effort</i>	<i>Medium Effort</i>	<i>High Effort</i>
Domestic Refrigeration – Refrigerant	DP	SP	
Domestic Refrigeration – Blowing Agent	DP	SP	
Commercial Refrigeration – Refrigerant	DP	SP	
Commercial Refrigeration – Blowing Agent	DP	SP	
Transport Refrigeration – Refrigerant	DP/SP		
Transport Refrigeration – Blowing Agent	DP/SP		
Industrial Refrigeration – Refrigerant	DP/SP		
Stationary Air Conditioning – Refrigerant	DP	SP	
Other 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*
PU Boardstock – Blowing Agent			DP/SP*
PU Spray – Blowing Agent			DP*/SP*
PU Block – Pipe		DP	SP
PU Block – Slab		DP	SP
Other PU Foams – Blowing Agent			DP/SP*
Halon – Fire Suppression	DP	SP	

DP = Densely Populated Areas; SP = Sparsely Populated Areas

\* Still technically unproven

Based on the form of analysis set out previously, the following graphs illustrate the predicted material flows for the period from 2010 to 2030.

**Figure 3-2: Time Series of ODS Arisings based on Low Effort Only**

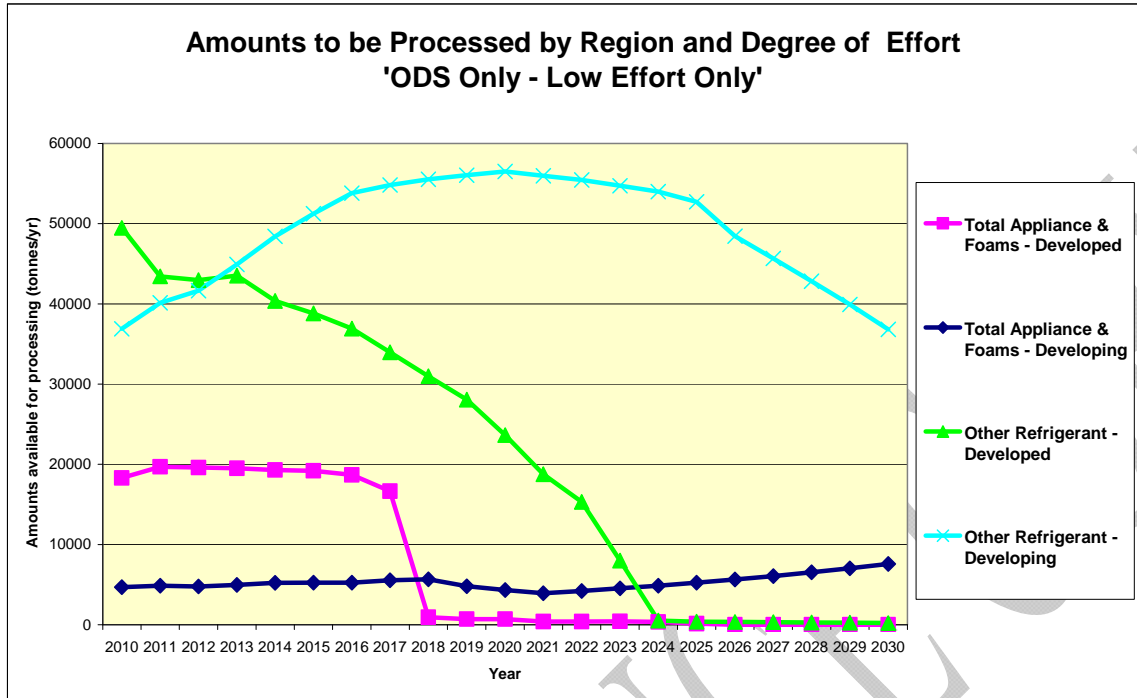
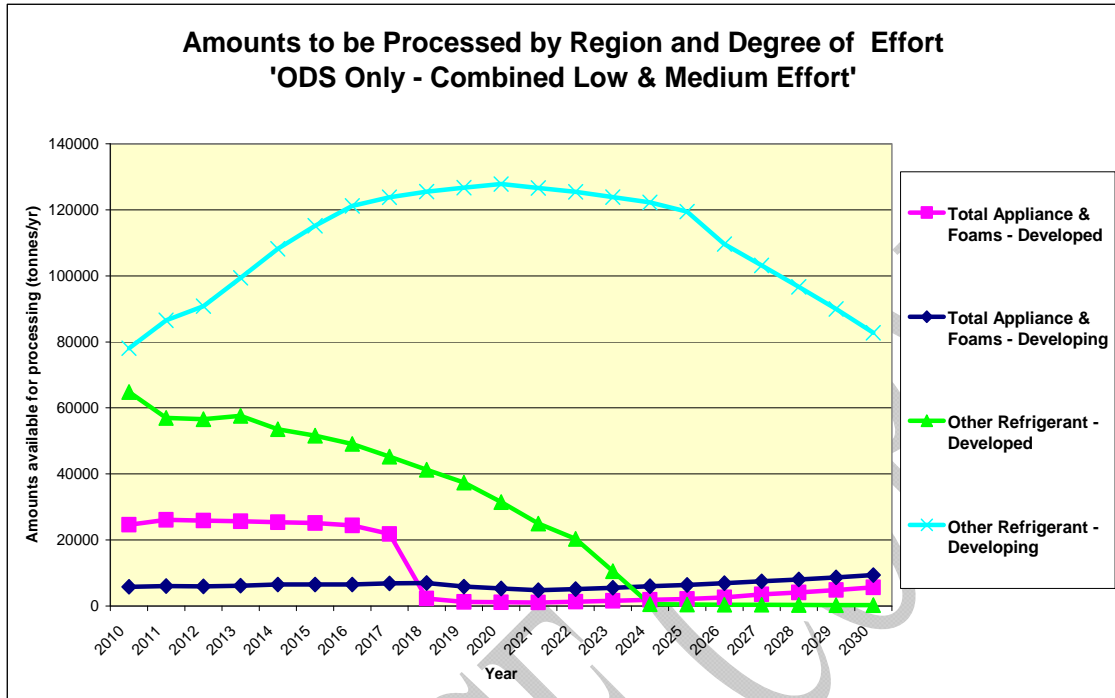


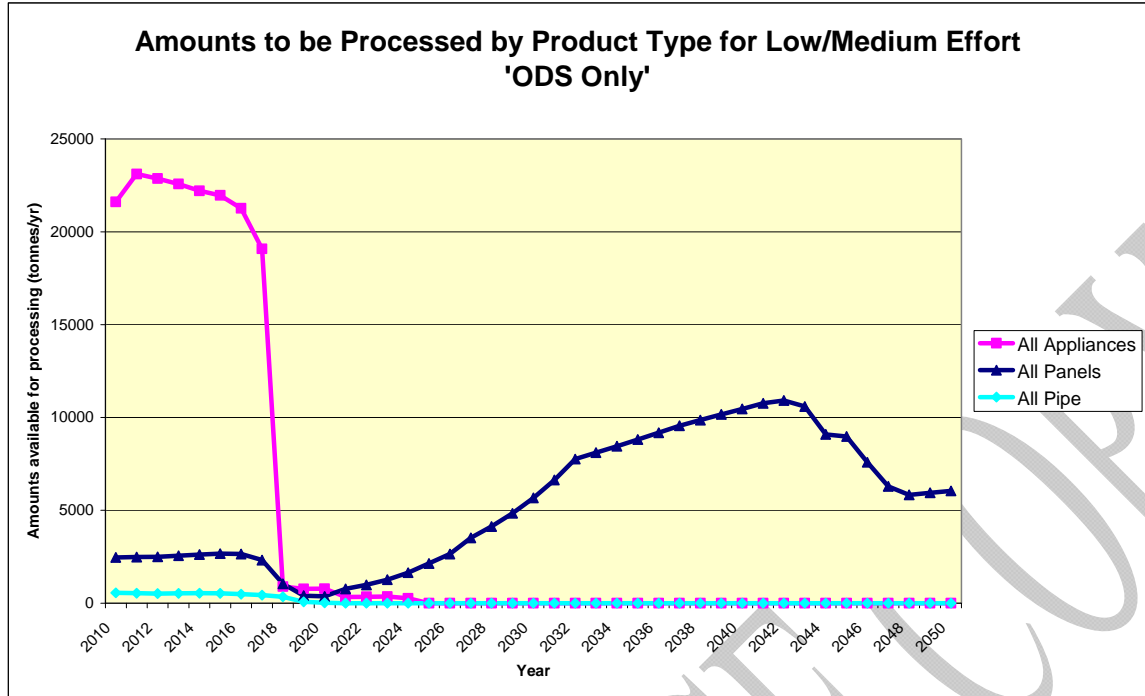
Figure 3-2 reveals a consistent theme throughout this report in that annual arisings from refrigerants are likely to dominate the material flows up to 2020 in developed countries and throughout the period in developing countries. The other major theme is that focus on ODS material recovery only, results in flows that fluctuate widely and would make for difficult investment circumstances for businesses operating in the field. The overall conclusions are not significantly altered when medium effort sources are additionally considered. However, the peak level of recovery increases to in excess of 120,000 tonnes/year and is maintained at that level for the period from 2015 to 2025, as shown in Figure 3-3 below.

Figure 3-3: Time Series of ODS Arisings from Low and Medium Effort Sources



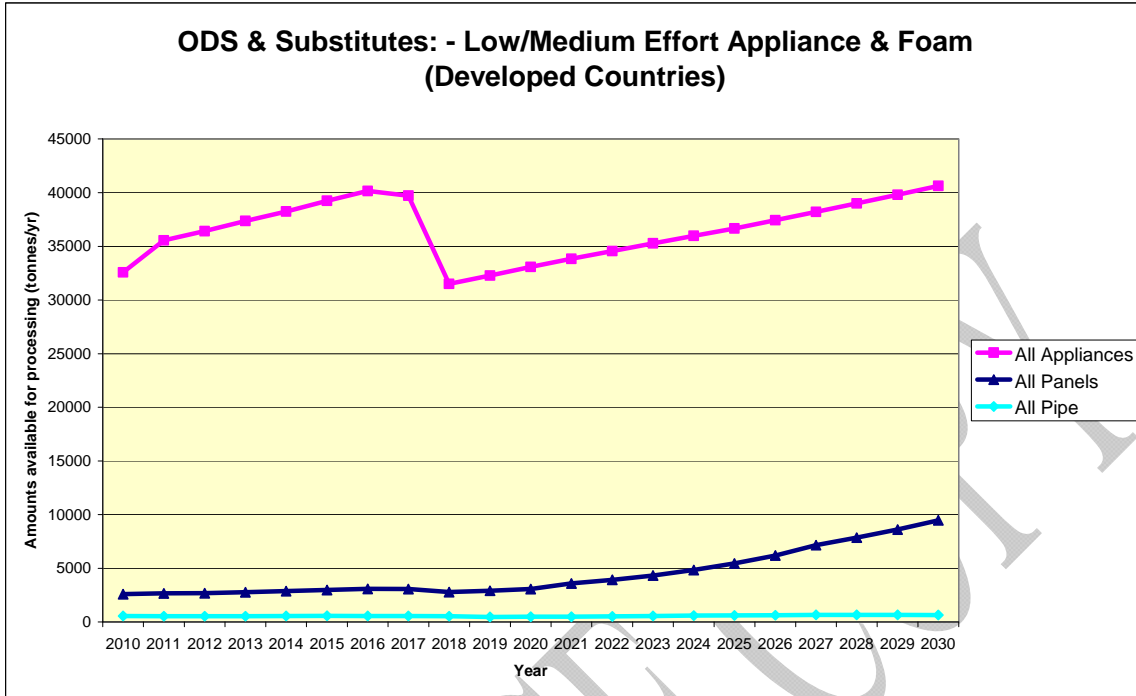
The increased recovery predicted in developing countries arises primarily from the inclusion of potential collections of ODS from the more rural areas, which were identified in the Phase 1 Report as accounting for almost 57% of the total population. It can also be seen that the inclusion of medium effort sources does little to increase the overall recovery levels in the “Appliances and Foams” category significantly in the period to 2030. This reflects the fact that the bulk of appliances have been managed in developed countries well before 2020 and that building foams only begin to emerge in the post-2030 time period. Figure 3-4, overleaf provides a view of the specific situation for “Appliances and Foams” in developed countries in this regard.

Figure 3-4: ODS Arisings from Appliances and Foams in Developed Countries



This graph only serves to reinforce the discontinuities in material flow that might result when focus is placed only on ODS recovery and destruction. Figure 3-5 illustrates how the inclusion of ODS substitutes of various kinds can create a more sustainable business model.

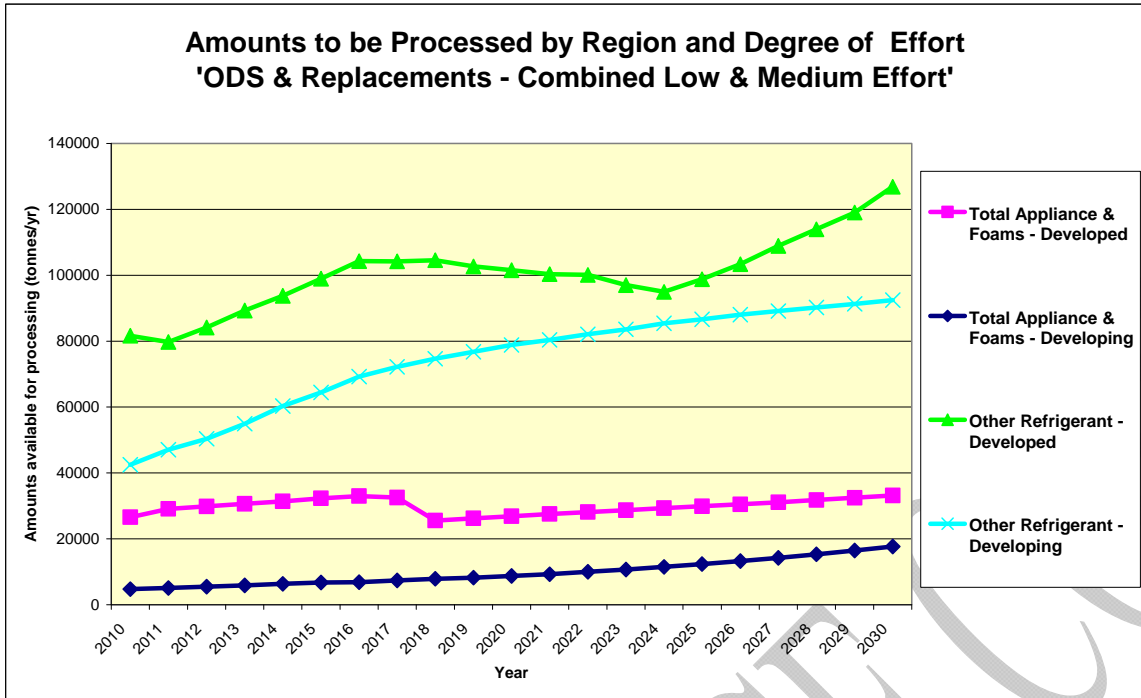
Figure 3-5: Impact of considering ODS and ODS Substitutes on total arisings



The step-change observed in the developed country appliances analysis occurs as a result of the more expeditious use of HFCs in North American appliances, where the foams are co-blown with CO<sub>2</sub> (water).

Addressing both ODS and ODS Substitutes has a wider effect on the material flows overall and opens up the possibility of using the same basic infrastructure for recovery of ODS Substitutes once the ODS flows have reduced. The stabilisation of flows is illustrated in Figure 3-6.

Figure 3-6: Stabilisation of flows based on addressing ODS and Substitutes

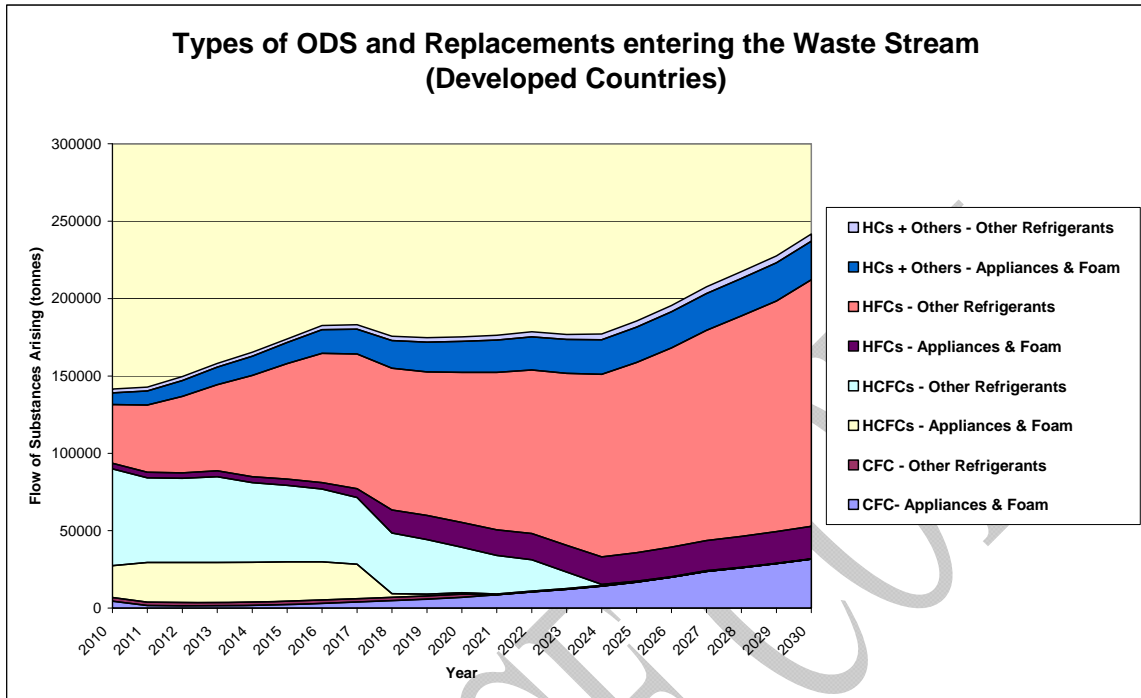


However, this raises the question as to whether the environmental benefit arising from the management of ODS Substitutes alongside residual ODS in the waste stream is sufficient to justify the maintenance of any infra-structure. This, in turn, needs a review of the mix of substances likely to be managed under the regional and sectoral scenarios considered. This is the subject of Section 3.4 of the Report.

### 3.4 Changes in the Mix of Substances Arriving in the Waste Stream

As already suggested in Section 3.1, the mix of substances arising year-on-year may vary significantly between developed and developing countries. The likelihood is that transitions from CFCs to HCFCs and onward to HFCs and hydrocarbons will be seen in most sectors and waste streams. Owing to different technology transition schedules in developed and developing countries, this can result in a relatively complex set of flows by substance type and source. Figures 3-7 and 3-8 show the substance mixes predicted in developed and developing countries respectively:

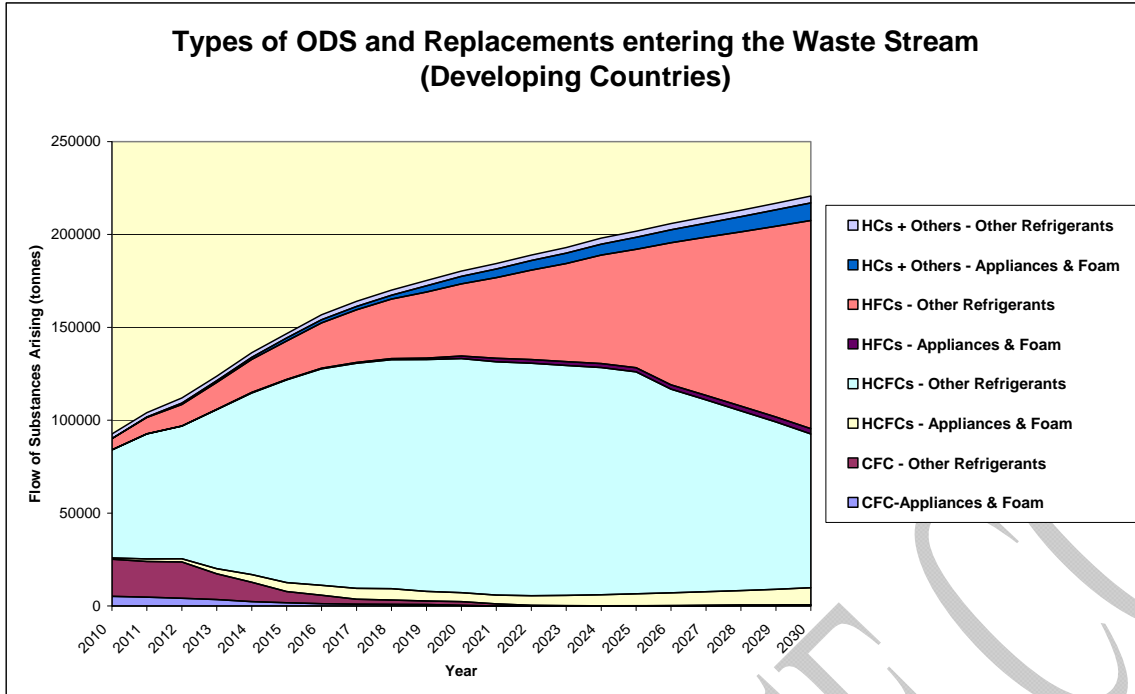
**Figure 3-7: Types of ODS and Replacements predicted to enter the waste stream (Developed Countries)**



The growth in importance of HFC-containing refrigerants is self-evident in this instance, but is less pronounced in Figure 3-8 where the introduction of HFC-blends comes later following the transition from HCFC-22.



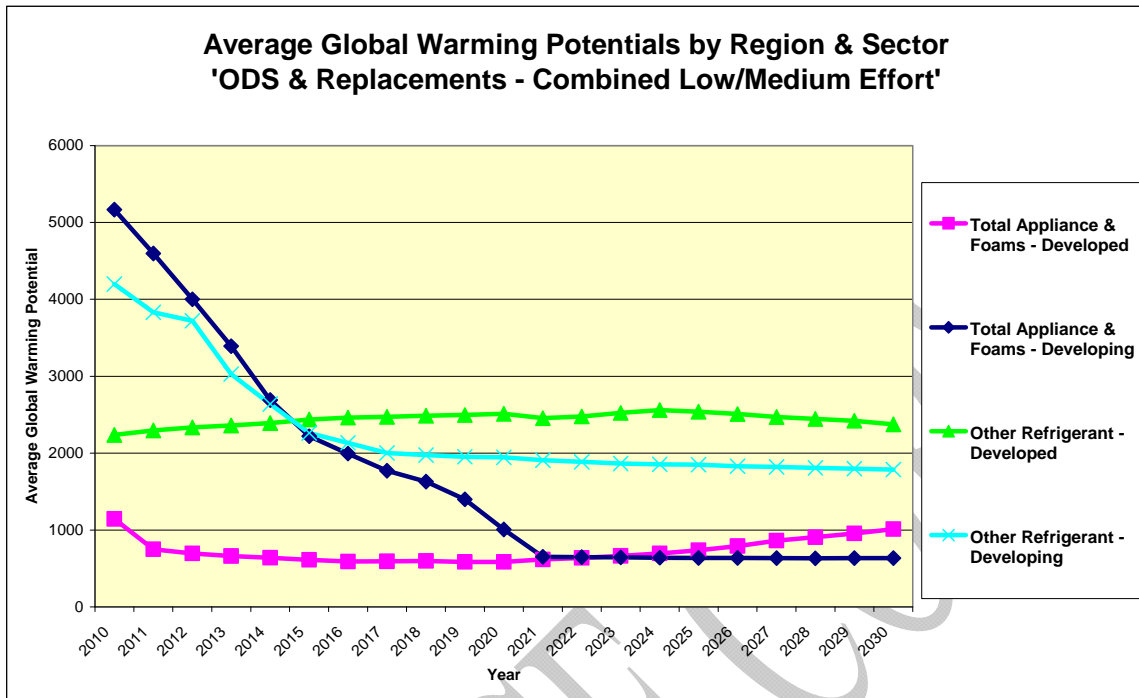
*Figure 3-8: ODS and Replacements predicted to enter the waste stream (Developing)*



The residual CFC-bank is also more evident in the Developing Country scenario and is not fully dealt with, even in the low and medium effort categories until after 2020. The other clear message from Figure 3-8 is that arisings will continue to grow overall in the developing country region.

Apart from the time-related changes in overall ODS flows that occur, there is a further factor that needs to be taken into account related to the change in substance mix with time. Since the global warming potentials (GWPs) of CFCs are generally higher than for HCFCs, it can be expected that the average climate benefit of the mix will decrease with time. This is most easily assessed by plotting the trends in average GWP with time for each of the waste streams. The analysis conducted for this Report shows that these trends are very similar for both low and medium effort categories, so Figure 3-9 focuses on the combined trend arising from low and medium effort categories.

Figure 3-9: Trends in Average Global Warming Potentials by Waste Stream Source



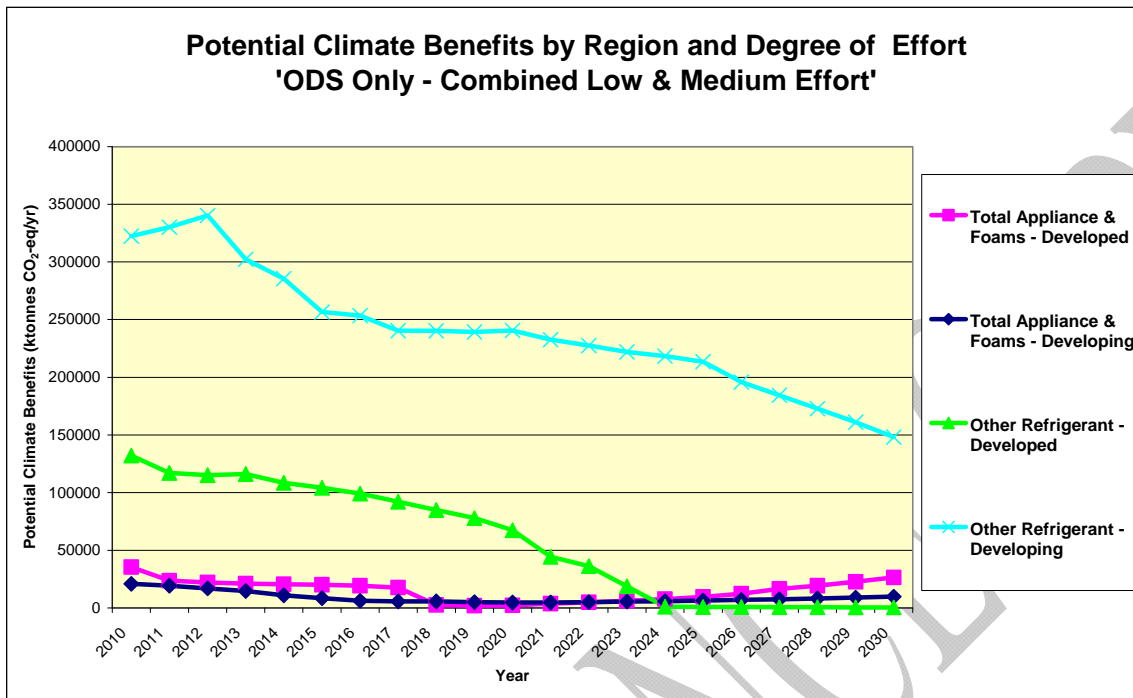
The graph illustrates the impact of residual CFC-11 and CFC-12 in the “Appliance and Foams” sector in developing countries. This is slightly less pronounced in the case of “Other Refrigerant” sources because of the historical role of HCFC-22 in some of these sectors. It can also be noted that the only significant upward trend in average GWP occurs, as expected, within the “Appliance and Foams” sector in developed countries as steel-faced panels begin to enter the mix of ODS into the waste stream. In this instance, the blowing agents would typically still be CFCs.

Both the overall climate benefit and the average climate benefit are important factors when determining the value of making an investment to destroy ODS. Bearing in mind that the investment needs to be made up-front, the continued operation of a plant might be justified on the basis of the marginal climate benefit delivered by destroying ODS Substitutes thereafter. This could be particularly the case where there is a regulatory imperative for recovery and destruction.

Where ODS recovery and destruction might be funded through carbon or other financial mechanisms, the incremental funds generated for each tonne of ODS destroyed would become a more important part of the business case. It could therefore be envisaged that a falling average global warming potential could lead to a point at which further recovery and destruction would be uneconomic and the operation of the recovery/ destruction facility suspended. This would depend also on the value placed on carbon at the time. These issues are further discussed progressively in Sections 6 and 7.

The following graphs show the regional evaluation of the accrual of overall climate benefit with time for both the ODS-only scenario and that including all ODS Substitutes.

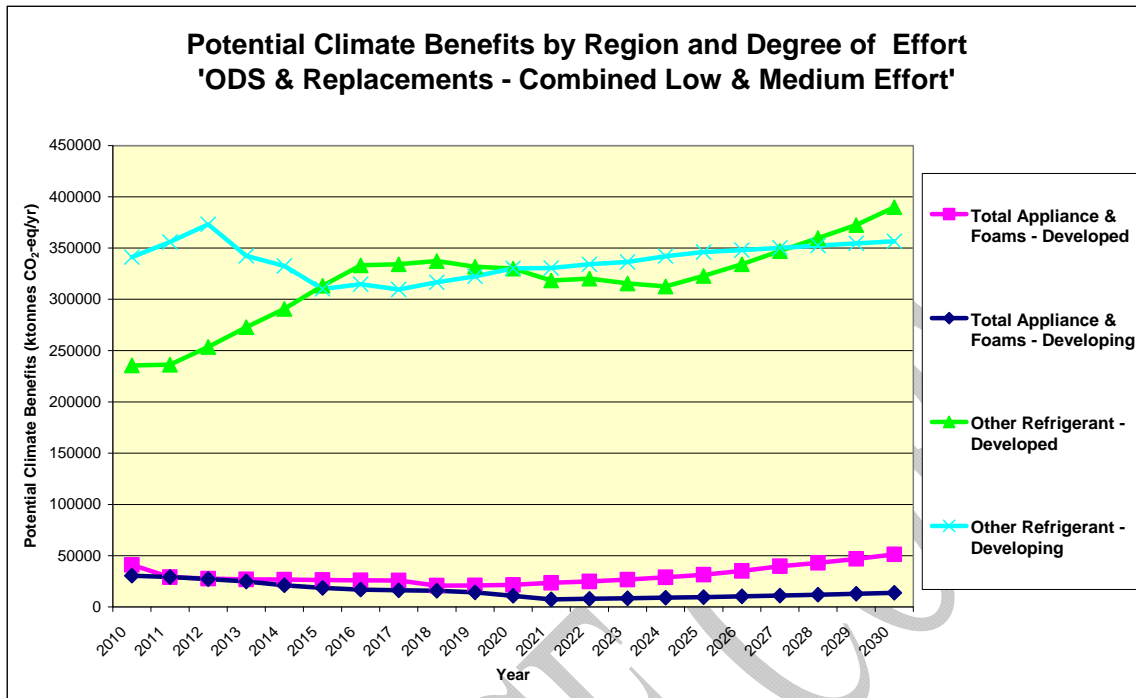
*Figure 3-10: Overall Climate Impact of Managing ODS Waste Streams*



It can be seen that the higher component of CFCs in the Developing Country waste streams has a marked impact on the annual climate benefit achievable. In the early years, this exceeds 300 Mtonnes CO<sub>2</sub>-eq. annually, but reduces by half in the period to 2030. Meanwhile, the climate benefit of managing ODS waste arisings alone in developed countries will have largely disappeared by 2025.

Again, introducing the effects of ODS Substitutes provides a more “encouraging” picture, as shown in Figure 3-11.

Figure 3-11: Climate Impact of including ODS Substitute Waste Streams



In this instance, it can be seen that recovery of all “Other Refrigerants” can sustain an annual recovery level of greater than 300 Mtonnes CO<sub>2</sub>-eq. for *both* developed and developing countries beyond 2015. The growth to that level in developed countries arises from a gradual increase in average GWP reflecting the previous replacement of HCFC-22 with HFC-blends. These trends are further assessed by level of effort in Section 4.2.

### 3.5 Sensitivity to the Life-time Assumptions (e.g. Domestic Refrigerators)

Section 3.1 has already given some discussion on the influence of lifetime assumptions on the substance mix arising annually within the waste stream. In Section 3.4, the importance of substance mix to the on-going financial case for recovery and destruction has also been considered. It is therefore clear that some provision must be made in regional estimates for the evaluation of the sensitivity to lifetime factors.

As a general principle, surveys of ODS arrivals into the waste stream should be conducted regularly, wherever this is possible, in order to augment and support the vintaging approach being taken. At sub-regional level, it would be expected that any vintaging model should be sufficiently versatile to be adjusted in accordance with experience and effectively become a ‘living document’ in any sub-regional ODS bank management strategy. This is particularly the case in circumstances where local factors might intervene (e.g. early retirement programmes).

Another factor that may be exposed using this type of cross-referencing process is the tendency for domestic refrigerators to be adopted for secondary use as beer coolers or, even as cupboard space when their functioning life is over. These trends can be highly country or sub-region-specific and can often be estimated from a good knowledge of local custom and practice.

Yet another intervening factor at this time is the potential impact of the recent economic crisis on purchasing behaviour. There is clear evidence to suggest that the level of new purchases has dropped away substantially in the last 18 months and has resulted in the longer retention of existing refrigerator models. It has been impossible to quantify this characteristic, but refrigerator recyclers continue to report higher levels of CFC-containing appliances than expected at this stage of the product cycle. However, it should be noted that the sub-regional variation remains a much more significant element, with average lifecycles for domestic refrigerators ranging between 11 years and 22 years depending on social behaviour patterns.

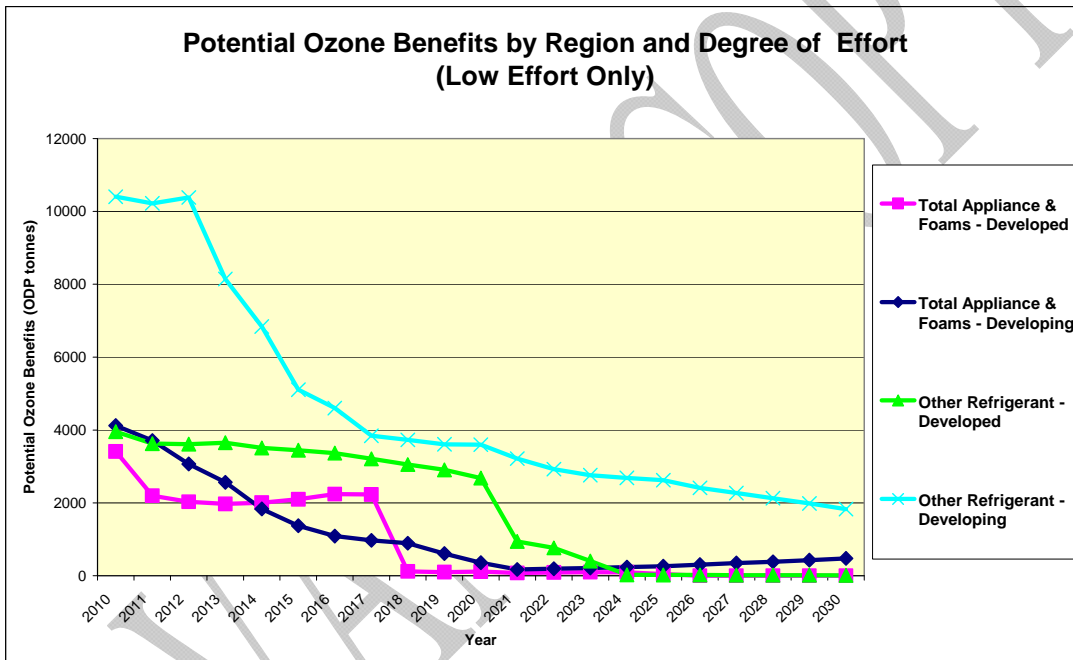


## 4 Environmental and Other Benefits accruing by Degree of Effort

### 4.1 Ozone Layer Benefits

The ozone layer benefits arising from measures taken within low and medium effort ODS bank categories are, of course limited to CFCs, HCFCs and blends containing them. The following graphs illustrate the potential annual benefits arising in avoided future ODS emissions, measured in ODP tonnes.

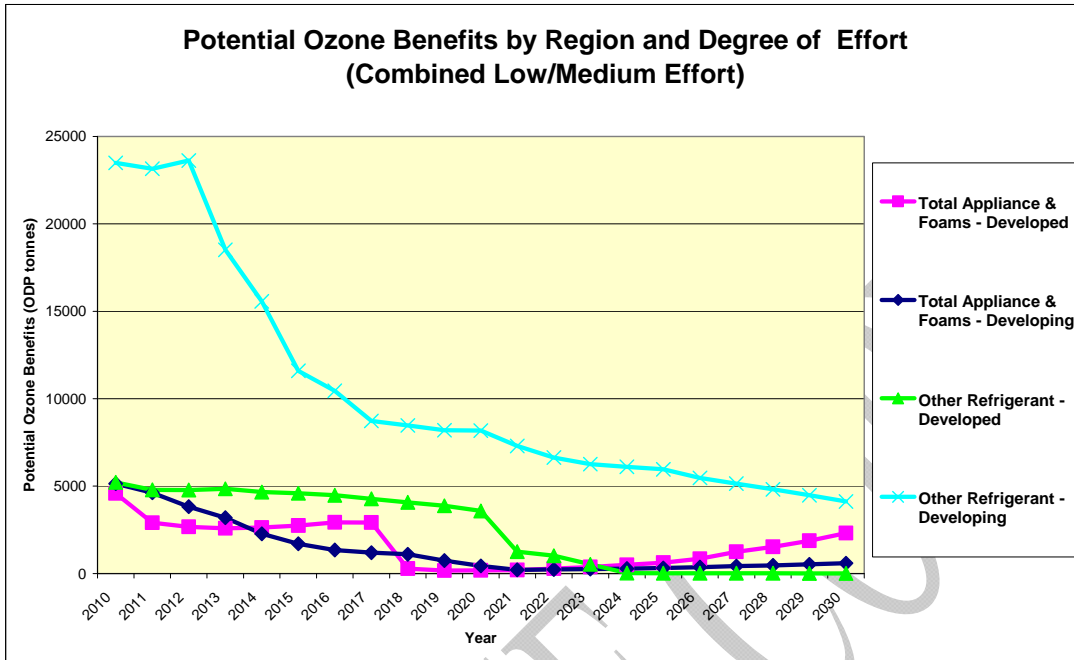
*Figure 4-1: Ozone Benefits Accruing from ODS Waste Stream Management (Low Effort)*



The cumulative savings in the period 2010-2030 from all four sources would be approximately 177,000 ODP tonnes for low effort sources only, increasing to approximately 332,160 ODP tonnes when medium effort sources are also included. The annual potential ozone benefits are shown in Figure 4-2 overleaf.

The increase in overall savings in ozone terms reflects the prominence of developing country refrigerant sources and the fact that a significant proportion of these will be found in rural (sparsely populated) areas. As can be seen from Figure 4-2, the initial annual savings from these sources alone may be in the 20,000-25,000 ODP tonnes range annually for the early years of any global ODS bank management project.

**Figure 4-2: Ozone Benefits Accruing from ODS Waste Stream Management (Low and Medium Effort)**



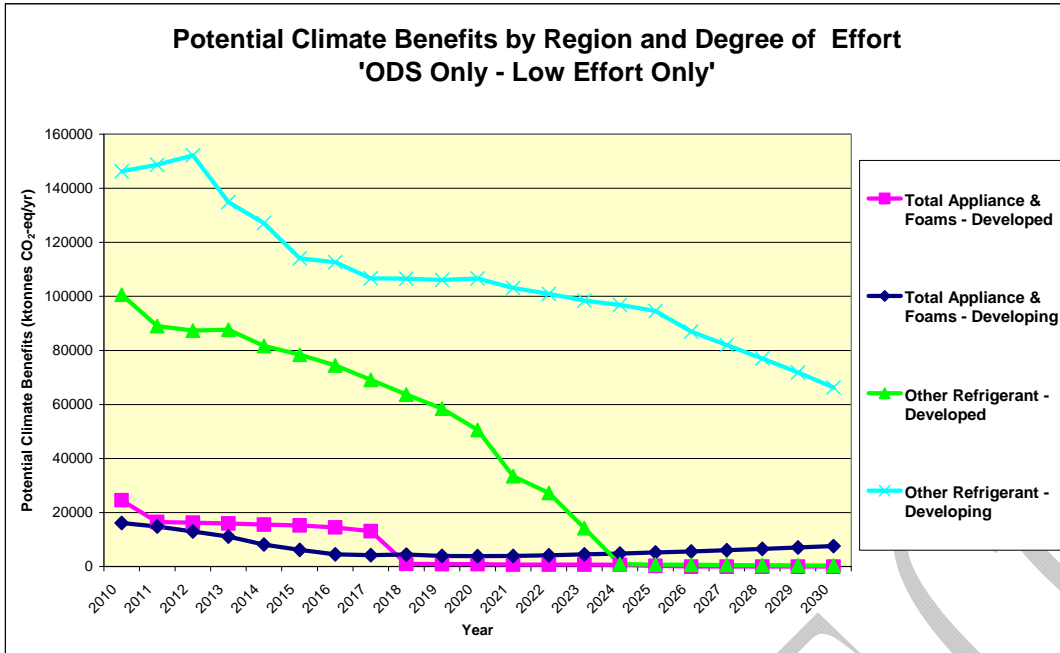
#### 4.2 Climate Benefits

An overview of the potential climate benefits has already been provided in Section 3.4, but this is now assessed in more detail by level of effort. Figure 4-3 provides a view of the climate benefit from the management of ‘low effort’ ODS Banks.

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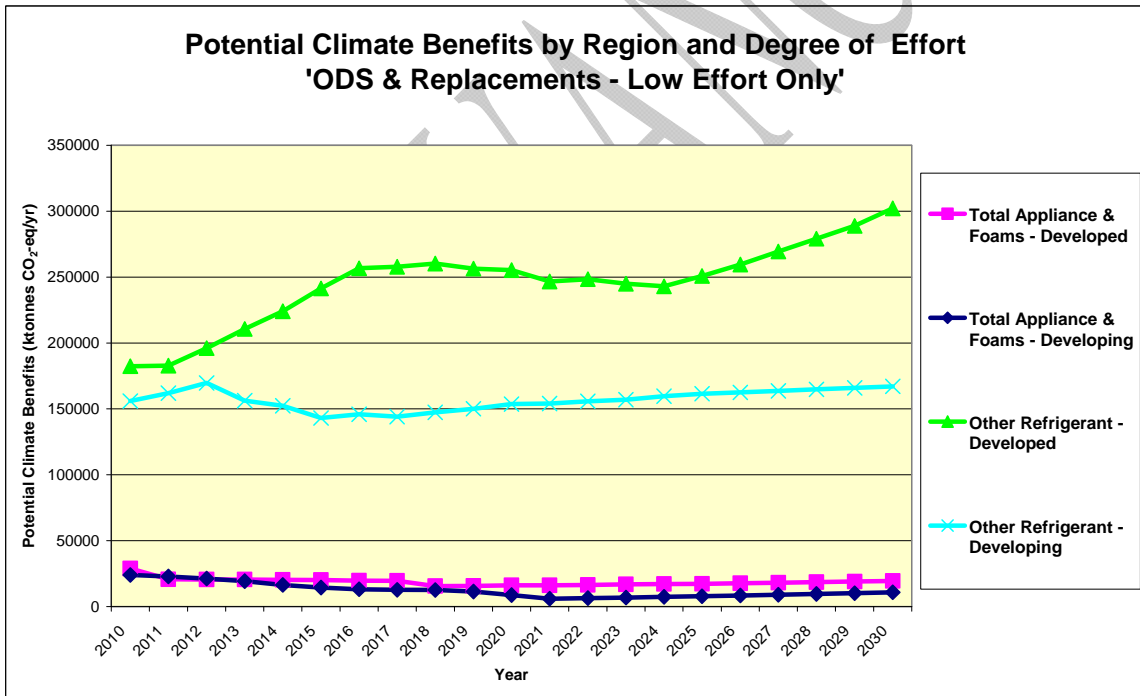


**Figure 4-3: Potential Climate Benefits from ODS Waste Stream Management (Low)**



When ODS Substitutes are included in the recovery and destruction strategy, the potential climate benefits increase accordingly, as shown in Figure 4-4.

**Figure 4-4: Potential Climate Benefits from ODS & ODS Substitute Management (Low Effort)**



It is interesting and relevant to compare Figure 4-4 with Figure 3-11 in order to see the impact of not addressing the medium effort banks in the Other Refrigerants category for developing countries. The impact is typically to reduce the potential climate benefits by approximately 150-200 Mtonnes CO<sub>2</sub>-eq. per year. It therefore becomes relevant to assess whether the costs of managing medium effort banks in developing countries can be supported.

### **4.3 Other Environmental Benefits**

It is rare that any end-of-life management programme takes place in isolation. In many countries there is considerable overlap between wider waste management and recycling programmes on the one hand and the safe management of hazardous materials on the other. In Japan, for example, the ODS Regulation covering end-of-Life management was built on the existing Producer Responsibility requirements for appliance manufacturers. In Europe, the development was the other way around with the ODS Regulation coming ahead of the Waste Electrical and Electronic Equipment (WEEE) Directive, but being cemented by it.

In the United States the interaction is even more complex. The regulatory requirement for the recovery of ODS refrigerant made it necessary to separate domestic refrigerators out of the general waste stream. The fact that these appliances were already being separated provided a focus for the metal recyclers to reclaim the steel and other metallic parts. This defined stream now provides an opportunity to manage the foam within the carcasses of the appliances.

These interactions are not exceptional but routine and it is clear that measures triggered within one area can have synergistic effects in others. This fact leads to wider questions about the way in which the costs of end-of-life management should be allocated. Although the costs associated with ODS bank management are, in themselves, relatively large, there can be direct synergistic benefits from actions such as steel recycling (often immediately discounted from the overall cost of ODS management) and the safe management of other hazardous materials.

There is, however, a potential complication when the basic health of the business model for ODS recovery depends on the receipt of synergistic revenues. As an example, in the recent economic downturn, a number of recycling markets have virtually collapsed leaving refrigerator recyclers with uneconomic facilities. The choice is often between ceasing operation altogether or finding ways of lowering costs. This can sometimes lead to short-cuts which are detrimental to the integrity of ODS recovery and destruction.

In the building-related sector, the business models are yet to fully emerge, since the flow of ODS from these sources is still at a relatively low level. However, as pressure increases to recycle building materials, driven by the need to increase the recycled content of new buildings, it is expected that segregation of demolition

waste will increase over time. Many demolition waste contractors are of the view that segregation is, in most cases, technically feasible, but will ultimately be driven by the incentives to do so (regulatory or fiscal). In many developed countries the management of non-domestic building decommissioning is becoming more rigorous and frameworks may already exist in which to slot ODS management requirements.

The critical question in all of these cases is whether the costs of ODS recovery can be defrayed across this wider agenda. It is clear that this may be possible in part, but quantifying the impact will depend on the cost-allocation methods used. This can only be assessed on a case-by-case basis and is beyond the scope of this report to predict.

#### **4.4 Social and Economic Benefits**

The growth in size of the global environmental industry has been self-evident in the last 20 years [reference?]. The management of ODS Banks which is already occurring has contributed to that growth. However, the approach taken in many developed countries has been to automate processes as much as possible to limit costs in regions where employment costs are high.

More recently, the economic downturn has resulted in a change in this philosophy, particularly in the United States where a ‘stimulus package’ has been launched with the primary purpose of encouraging the generation and/or retention of jobs.

Over 20 US States have submitted proposals for refrigerator recycling activities under this scheme and the bulk have been based on semi-automated plant designs, leaving the foam segregation to be managed manually prior to low energy recovery of the ODS from the foam (avoiding the energy-intensive shredding of the steel).

Although it is unreasonable to make a precise assessment of likely employment impacts of wider ODS bank management at this stage, a simple pre-assessment would suggest that a spend of US\$ 150 billion spread over 30 years could result in 1,000 jobs per year based on an average employment cost of US\$ 50,000 per employee-year. This would be likely to fluctuate with the ODS flows, both temporally and regionally, but could be an important benchmark.



## 5 Sub-regional Examples of ODS Banks entering the Waste Stream

### 5.1 European Union (and/or Countries therein)

The European Union has regulated the end-of-life of ODS-containing products and equipment since the introduction of EC Reg. 2037/2000 in the year 2000. The regulation has focused primarily on the management of refrigerants and fire suppressants, although foam blowing agents were included when the requirement for ODS recovery from foams in domestic refrigerators was introduced on 1<sup>st</sup> January 2002.

This requirement necessitated investment across Europe in refrigerator recycling facilities which have managed both the removal of refrigerant and foam blowing agent from domestic refrigerators. Although recovery levels from individual units have been relatively good (albeit not always meeting the exacting requirements of the RAL standard), the overall level of enforcement of the regulation has resulted in less than optimal overall coverage across the EU. Some estimates suggest that coverage may not have exceeded 50% of the available refrigerators and freezers reaching the waste stream.

The introduction at national level of the Waste Electrical and Electronic Equipment (WEEE) Directive took a wider view of the management of domestic refrigerators/freezers and required both ODS and HFC refrigerants and blowing agents to be managed at end-of-life. Owing to the more wide-ranging nature of the WEEE Directive, it has attracted more attention from Member State Governments and has resulted in the greater practice of end-of-life refrigerator management.

The management of other foam types has been left more open, with EC 2037/2000 requiring their recovery only 'if practicable'. This language has caused much discussion over the intervening years, particularly because it has both technical and economic connotations, but the issue has been of largely academic interest to date, because most of these foams (typically used in buildings) have not yet entered the waste stream. Nonetheless, there have been examples involving steel-faced panels (e.g. SEPA 2006) where the '*practicable*' language has been deemed to apply. In an effort to address this issue, the Commission, in its recent re-cast of the Ozone Regulation, has sought to introduce a mechanism to develop a positive list of products for which recovery of blowing agents is technically feasible.

This discussion is important for the future, since the foam bank represents the most significant single source of ODS release over the next 30-50 years. The following table provides a summary of the projected EU bank size in 2010 as derived within the Milieu/EcoSphere Report published in late 2007.

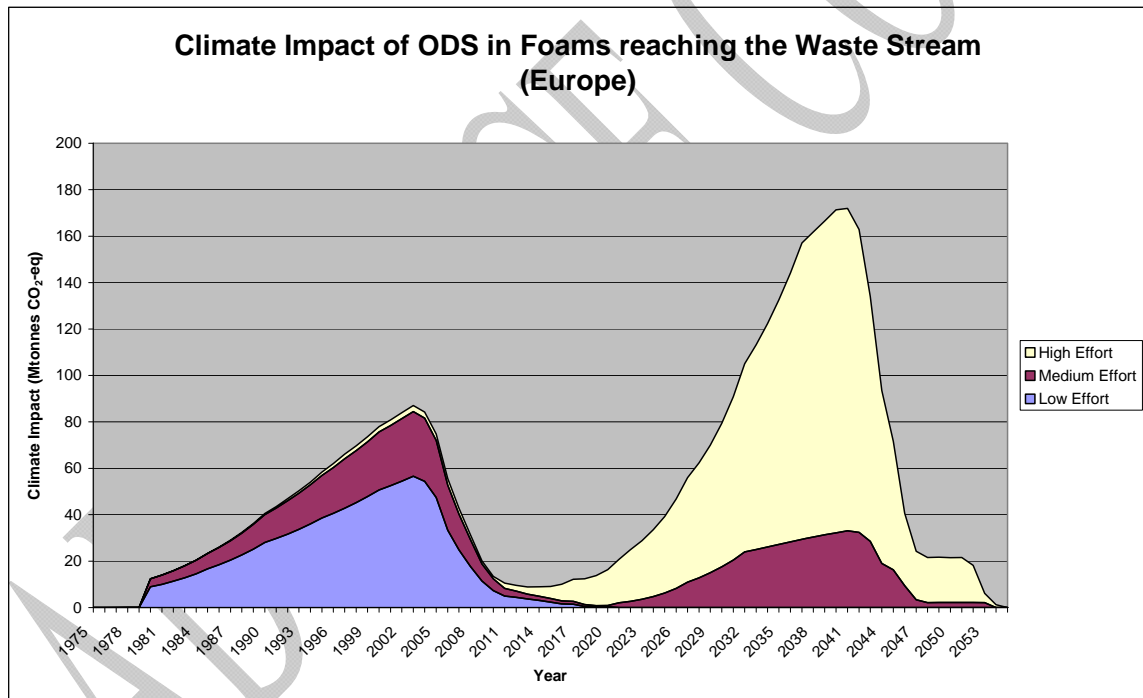
**Table 5-1: Predicted ODS Banks in the EU in 2010**

<b>ODS</b> <i>(ktonnes)</i>	<b>Refrig. &amp; A/C</b>	<b>Foams</b>	<b>Fire Suppressant</b>
CFC	112.4	531.2	-
HCFC	281.4	237.5	-
Halon	-	-	18.1

The table illustrates that the bank overall is equally split between CFCs and HCFCs, but this hides the fact that the impact in both ozone and climate terms arises from the large component of CFCs in foams.

This Report has assessed how these banks might be expected to emerge into the waste stream, based on the level of effort categories previously referenced in Table 3-1. The following graph gives this analysis over time.

**Figure 5-1: Climate Significance of Annual Arrivals from Foams into Waste Stream**



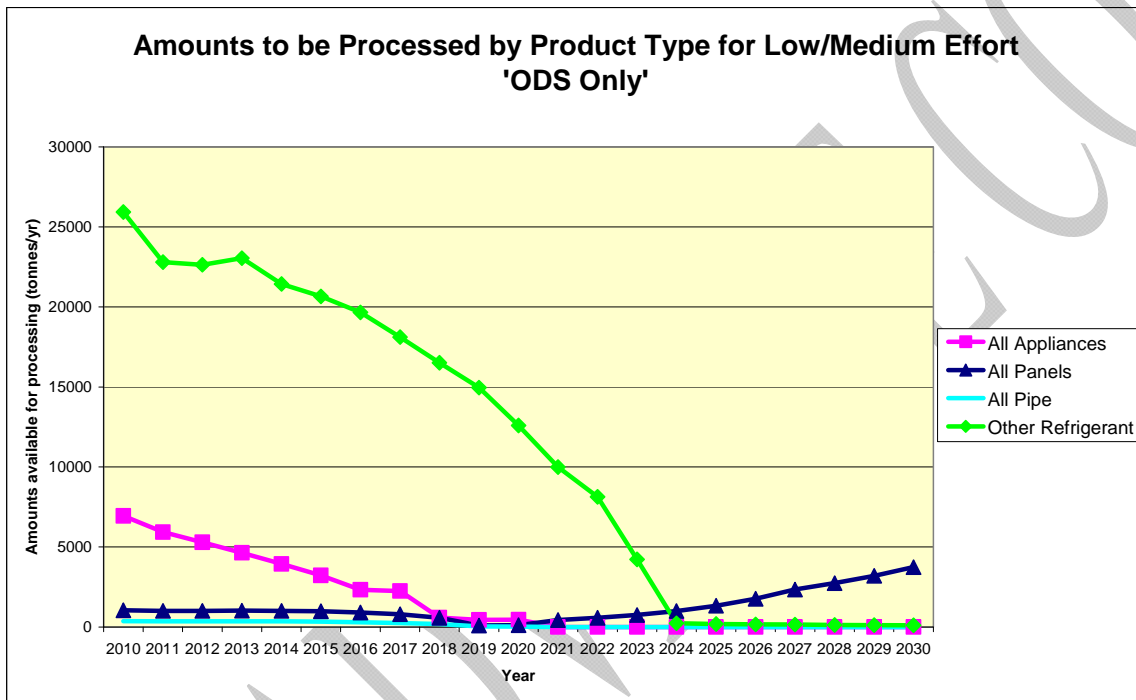
It can be seen from this graph that the introduction of EC 2037/2000 and its impact on refrigerators was just at the peak of the opportunity for low and medium effort recovery. Although steel-faced panels provide a medium effort opportunity for the future the bulk of the foam challenge is in the high level of effort category.

Since there is a potential that the steel-faced panel recovery and destruction could use the same equipment as that used for refrigerators, the dip in the annual flows

for the period from around 2012 to 2022 may cause difficulties in business sustainability in the interim. This said, there is evidence that refrigerator retirements may be a little later than is forecast by the 15 year lifecycle assumptions. This may be partly as a result of re-use as secondary unit or may relate to delays in replacement caused by the financial downturn. Either way, some refrigerator recycling companies are forecasting significant CFC-containing waste flows from domestic refrigerators well beyond 2015.

By far the most significant waste flow for ODS in the period to 2030 is forecast to be the recovery of refrigerants from other equipment types (e.g. commercial, transport, industrial, stationary A/C and mobile A/C). Figure 5-2 shows the flows expected in metric tonnes and compares them with other sources.

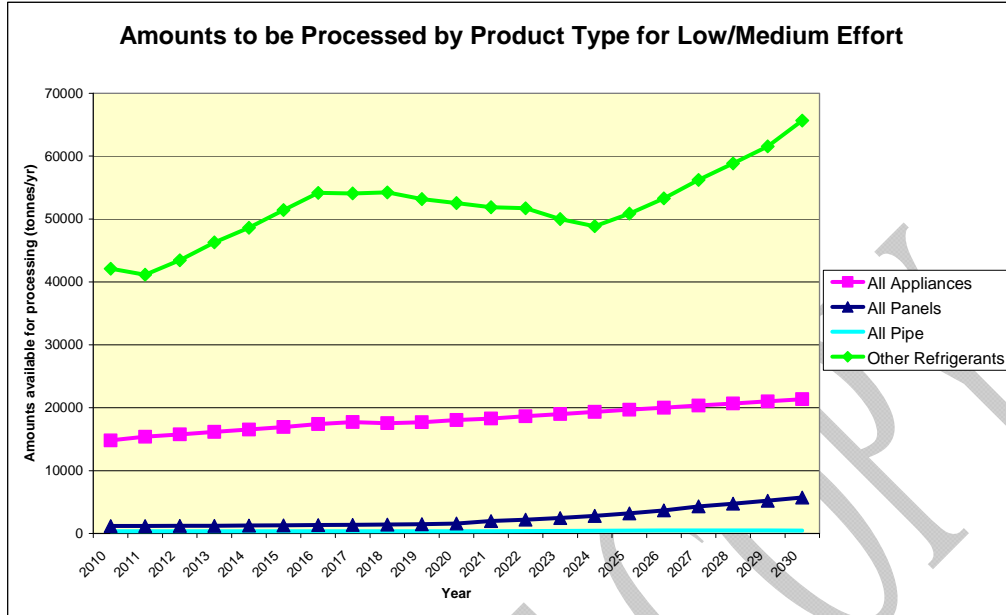
**Figure 5-2: ODS flows into the Waste Stream by Source in the period 2010-2030**



Again, the early phase-out of ODS in the European Union creates a scenario where the recovery mechanisms would become largely redundant in the period after 2025 until opportunities in the panel sector began to grow.

However, the more holistic approach foreseen under the WEEE Directive (i.e. the management of all refrigerant types) makes the prospect for end-of-life management of refrigeration equipment much more sustainable. Figure 5-3 illustrates the general stability and gradual growth of the flows into the waste stream if all ODS replacements are also managed.

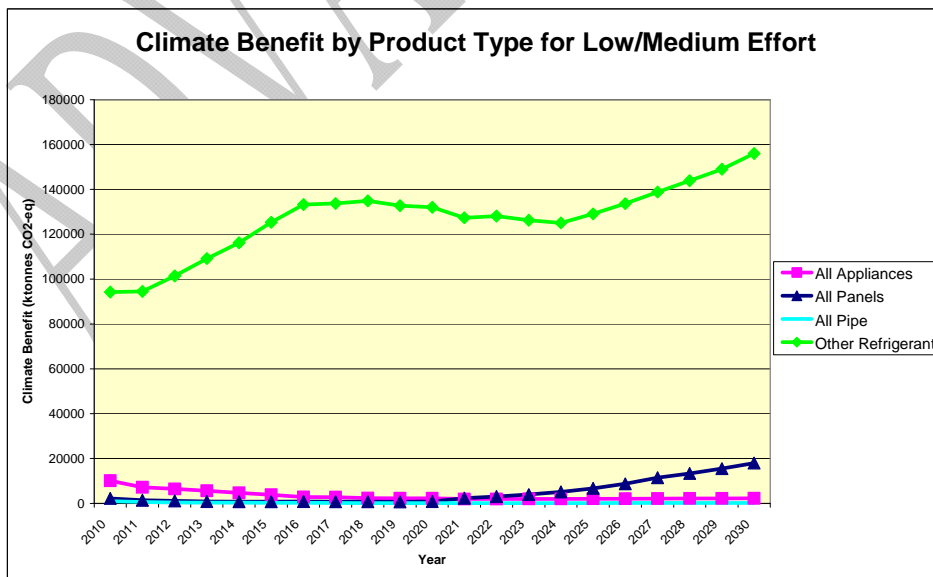
**Figure 5-3: Annual flows of ODS and Alternatives into the Waste Stream (2010-2030)**



For the appliances sector, the requirement to manage around 20,000 tonnes annually in typical refrigeration recycling plants would require between 110 and 120 units spread across Europe, based on the assumption that each facility could handle around 350,000 refrigerator units per year.

The difficulty in sustaining this approach is the relatively low climate benefit associated with hydrocarbon blowing agents and refrigerants. However, for other refrigerant types the situation is entirely the opposite, as shown in Figure 5-4.

**Figure 5-4: Potential Climate Benefit by Product Type(2010-2030)**



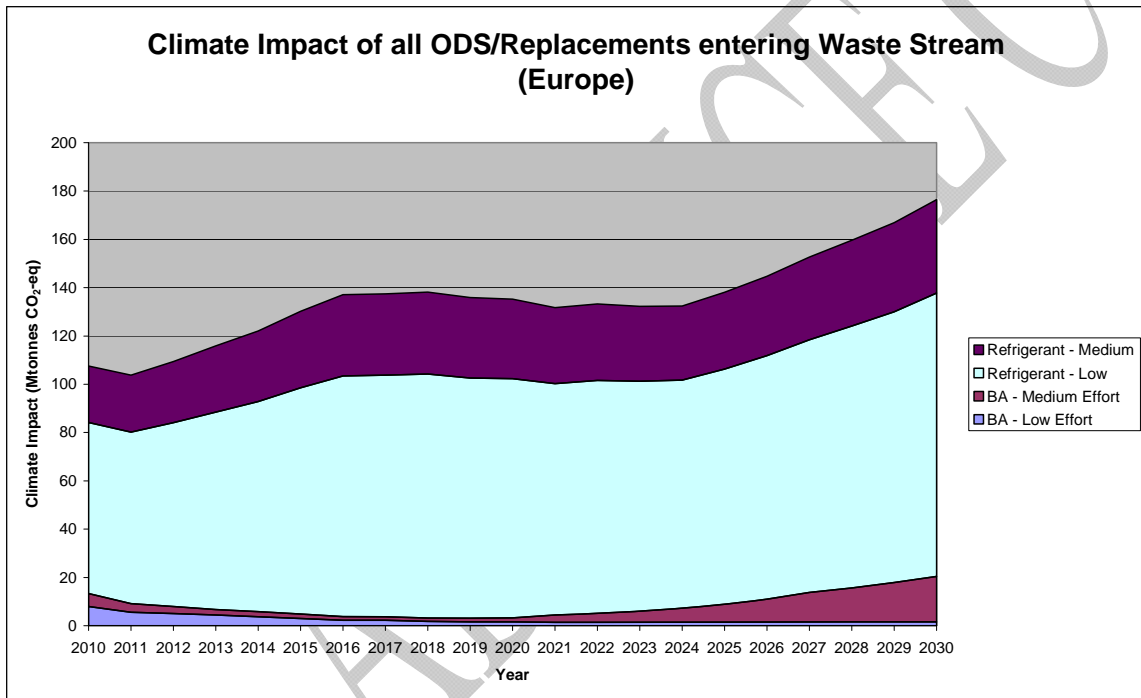


With an annual potential likely to range between 100-150Mtonnes CO<sub>2</sub>-eq. for the next 30 year period, there is clearly major value in ensuring that major collection, recovery and destruction activities are practiced at end of life for the major refrigeration equipment types.

One option would be to use the same centres as have been established for domestic refrigerators as collection and degassing facilities for other types of refrigeration and A/C equipment. However, this would only apply where there was a need to return that equipment in tact. For larger installations, the refrigerant is likely to be extracted on site.

In summary, the climate benefit of managing all low and medium effort sectors within the EU in the period from 2010 to 2030 can be viewed as shown in Figure 5-5. Recovery levels of around 175 Mtonnes CO<sub>2</sub>-eq per year can be expected by 2030.

**Figure 5-5: Aggregated Climate Benefit by Source & Level of Effort (2010-2030)**



## 5.2 Latin America (and/or Countries therein)

### Brazil

Based upon Ibope Institute data, Whirlpool has developed estimates for the age profile of the stock of refrigerators currently in use in Brazil. The projected characterization of this stock, as at 2010, is shown in Table 5-2 below:

**Table 5-2: Characterisation of Brazilian Refrigerator Stock**

	no. refrig. MM 2010	CFC-based %	foamed %	CFC-based MM	foamed MM	CFC-12 ton	CFC-11 Ton
	Total	43,8					
up to 3 years	14,8	0	100	0,0	14,8	0,0	0,0
from 3 to 5 years	9,0	0	100	0,0	9,0	0,0	0,0
from 6 to 10 years	10,0	0	100	0,0	10,0	0,0	0,0
from 11 to 15 years	7,1	50	85	3,5	6,0	707,6	645,0
above 15 years	2,9	100	40	2,9	1,1	573,8	123,1
Total bank (ton)						1281,3	768,1

It can be seen that only 40% of those appliances above 15 years old (i.e. liable for retirement in 2010) are filled with polyurethane foam. The remainder was insulated using glass wool. In addition, 50% reduced CFC formulations were used throughout the 1990s. The net effect is that quantity of CFC-12 available from these refrigerators significantly exceeds that of CFC-11. CFCs in general remained in use for new equipment until 2000. Accordingly, CFCs arisings could be expected until 2015 at least. It is interesting to note that the period of CFC use was surprisingly short in the Brazilian case. However, HCFC-based foam technologies and HFC refrigerant technologies were already beginning to take hold in the stock that will be between 11-15 years old in 2010.

Considering 2010 estimates, the number of CFC-based refrigerators still in use would be about 10 million, out of existing 43.8 million. Table 5-2 also shows the estimated amount of CFC banks in Brazilian refrigerators, considering 20 % losses out of an average 250 g charge, and 50 % loss of blowing agent in the aged foam.

It can be seen that the amount of CFC banks in Brazilian household refrigerators is approximately 2kt, corresponding to carbon contents of 17.6 Mt CO<sub>2</sub>e, being 14.0 Mtonne CO<sub>2</sub> eq. from CFC-12, and a comparatively reduced amount of 3.6 Mtonne CO<sub>2</sub> eq. from CFC-11, due to the lower GWP (4750 for CFC-11 vs. 10890 for CFC-12). Other environmental benefit of recovery and destruction of the CFCs present in these products is associated to the 50 % lower energy consumption of the current refrigerators compared to the ones manufactured in the 90's. The 50 % figure is highly conservative because it results from the comparison of declared values corresponding to new appliances.

## 5.3 Japan

### 5.3.1 Outline of Recovery and Destruction Policy in Japan

Japan is an island country comprising of main four islands, Hokkaido, Honshu, Kyushu and Shikoku. It lies to the east of Eurasia close to the Korean Peninsula.

The population is about 127,000,000 in 2008 and its area is about 377 thousands km<sup>2</sup>.

Annual shipment of CFCs, HCFCs and HFC was 185 thousands tonnes in 1989 which have been rapidly decreased to 58 thousands tonnes in 2002. Presently, the banked CFCs, HCFCs and HFCs are estimated to be about 300 thousands tonnes, of which 70 % is used in refrigeration, 20% in insulation foams, and the rest in solvents, aerosols and others.

The recycling and destruction of fluorocarbon waste have been regulated by the Fluorocarbons Recovery and Destruction Law enacted in April 1, 2002. These fluorocarbons include CFCs, HCFCs and HFCs both to protect the stratospheric ozone depletion and to mitigate the global warming.

On the other hand, the collection of waste equipment that contains the fluorocarbons is necessary for their segregation from the waste equipment. In parallel with fluorocarbon waste recovery, the regional waste minimization, so-called 3R, became important. Thus, in 1999 the government enacted the Fundamental Law for Establishing a Sound Material-Cycle Society, under which the Law for Recycling for Specified Kinds of Home Appliance entered into force in April 1, 2001, and the End-of-Life Vehicle Recycling Law in January 1, 2005. The waste of commercial and industrial refrigerators and stationary air-conditioners is recovered under the Fluorocarbons Recovery and Destruction Law.

**Table 5-3: Major equipment that contains fluorocarbons**

<i>Items</i>	<i>Equipment</i>	<i>Fluorocarbons in equipment</i>
Home appliances	refrigerators, room air-conditioners, insulation foams	CFCs, HCFCs, HFCs
Automobiles	mobile air-conditioners	CFCs, HFCs
Commercial refrigerators and stationary air-conditioners	commercial freezers refrigerators, air-conditioners	CFCs, HCFCs, HFCs
Buildings and houses	insulation foams	CFCs, HCFCs, HFCs
Fire extinguishers	fire extinguishers	Halons, HFCs

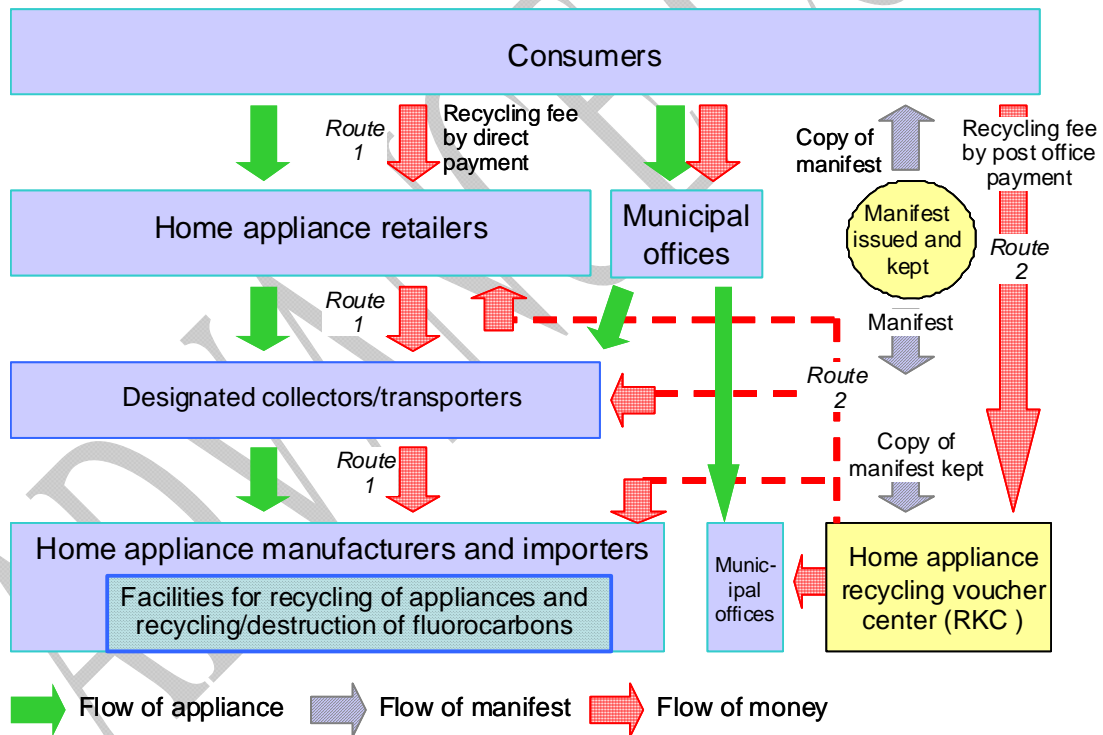
### **5.3.2 Electric Home Appliances**

Annual waste of the four appliances is about 600 thousands tonnes. Four kinds of home appliances waste, room air-conditioners, domestic refrigerators, washing machines and TV sets, have been presently recovered. In April 1, 2009, flat-screen TV sets were added to the appliances to be recovered.

The flow diagram of home appliance recovery and fluorocarbon destruction is shown in Figure 5-6. Consumers request the home appliances retailers to recycle the five types of appliances. The appliances are sent to the designated collectors of 380 sites, and their roles are acceptance, storage of the appliances. They also ask the transport firms for delivery of the appliances to the facilities for recycling of appliance and recycling/destruction of fluorocarbons. Small part of the appliances is accepted by municipal offices which submit it the designated collectors or recycle it by themselves.

Nationwide facilities for recycling of appliances and recycling/destruction of fluorocarbons are distributed in 48 sites. Parts and materials of room air-conditioners, washing machines, domestic refrigerators and TV sets are processed for reuse or recycling. At the same time, the facilities extract fluorocarbons from the room air-conditioners and domestic refrigerators. In case of the refrigerators, fluorocarbons in insulation foams as blowing agents are recovered and destroyed.

**Figure 5-6: Flow Diagram of Home Appliance Recovery and Fluorocarbon Destruction**



Consumers pay the recycling fees by choosing two routes: (1) direct payment at the appliance retailers, or (2) payment through post office to the Home Appliance Recycling Voucher Center (RKC).

Typical fees are US\$ 34 (3,150 yen) for a room air-conditioner, US\$ 27 (2,520 yen) for a washing machine, US\$ 52 (4,830 yen) for a domestic refrigerator, and

US\$ 31 (2,835 yen) for TV set, respectively. However, the fees for recovery and destruction of fluorocarbons are not clear.

In 2008 fiscal year from April, 2008 to March, 2009, about 12,790 thousands units of the four appliances were collected, and about 12,730 thousands units were processed for reuse, recycling and disposal. This corresponds to 496 thousands tonnes in weight. Materials such as iron (152, 822 tonnes), copper (15,131 tonnes), aluminum (10,624 tonnes), mixed metal (58,797 tonnes), glass (83,749 tonnes) were recycled to use in 2008 fiscal year. Ratios of reuse and recycling to the collected four kinds of appliances were 74% to 89%.

Recovery of fluorocarbons is listed in Table 5.4. The amount of refrigerants recovered from domestic refrigerators and room air-conditioners gradually increased while that of blowing agents slightly decreased probably because of replacement of CFC-11 to hydrocarbons such as cyclopentane. The destruction amounts of fluorocarbons shown in Table 5.5 were almost the same as the recovered amounts in Table 5.4 in each year, indicating that all fluorocarbons recovered were not recycled but destroyed.

**Table 5-4 Recovery of Fluorocarbons in Home Appliances (unit: kg)**

Fiscal year (April to next year's March)		2001	2002	2003	2004	2005	2006	2007	2008
Domestic refrigerators	Refrigerants	135,779	223,946	286,646	310,915	310,701	297,619	298,544	299,118
	blowing agents	-	-	-	625,490	607,753	592,511	574,535	556,754
Room air-conditioners	Refrigerants	467,316	806,580	860,496	994,732	1,122,462	1,043,778	1,089,423	1,166,887

**Table 5-5 Destruction of fluorocarbons in Home Appliances (unit: kg)**

Fiscal year (April to next year's March)		2004	2005	2006	2007	2008
Domestic refrigerators	refrigerants	312,257	309,734	297,868	298,145	301,307
	blowing agents	-	605,365	589,832	589,832	554,472
Room air-conditioners	refrigerants	976,479	1,117,923	1,047,979	1,084,342	1,170,356

### 5.3.3 Mobile Air Conditioners

A total of about 75,000 thousands automobiles are registered in Japan, in which 58,000 thousands are passenger cars and 16,000 thousands trucks and buses.

Estimated annual disposal of automobiles are about 7,000 thousands. A statistics of new production cars in 2002 indicates that more than 97% of passenger cars, trucks and buses, and more than 90% of light trucks are equipped with mobile air-conditioners. Since replacement of CFC-12 with HFC-134a completed in 1994, recent disposed mobile air-conditioners contain HFC-134a.

Similarly to the electric home appliances, under the Fundamental Law for Establishing a Sound Material-Cycle Society enacted in 1999, the End-of-Life Vehicle Recycling Law was enacted in January 1, 2005.

The recycling system was formulated by the Japan Automobile Recycling Promotion Center (JARC), as shown in Fig.5-7. Owners of automobiles deposit the recycling fee for fluorocarbon, airbag and shredder dust. End-of-life vehicles are first received by collectors who are about 88,000 new-car dealers, used-car dealers and maintenance factories. CFC-12 and HFC-134a are recovered by the fluorocarbon recovery operators. Dismantlers segregate engines, body parts, electric parts, exhaust catalyst, non-ferrous metals, tires, window glass, and so forth. Shredding residue processors receive final debris, 85-90% of which is recycled to use as parts and materials. Remaining 10-15% waste is returned to automakers and importers for further disposal. Figure 5.2 depicts flow diagram of end-of life vehicle recovery and accompanies recycling/destruction of refrigerants in MAC.

Almost 100,000 operators/agents are involved in the framework of ELV recovery. The fluorocarbon recovery operators of 18,046 have been registered.

In the year of 2008, 371,000 thousands ELV were generated and the collector received 279,000 thousands ELV, remaining 92,000 thousands directly transferred to the dismantlers. Fluorocarbons were recovered by the fluorocarbon recovery operators.

The recycling fees for processing fluorocarbons, airbag, and shredder dust and management are deposited when a new car is bought. Typical fee for fluorocarbon recycling is US\$ 22 (2050 yen). Total deposit fees are US\$ 110 to 140 (10,000 to 13,000 yen). The fees are refunded to the fluorocarbon recovery operators, dismantlers (airbag) and shredding residue processors by the Fund Management Center in JARC after confirmation of the manifests.

**Figure 5-7: Flow Diagram of End-of life Vehicle Recovery and Recycling/ Destruction of Refrigerants in MAC**

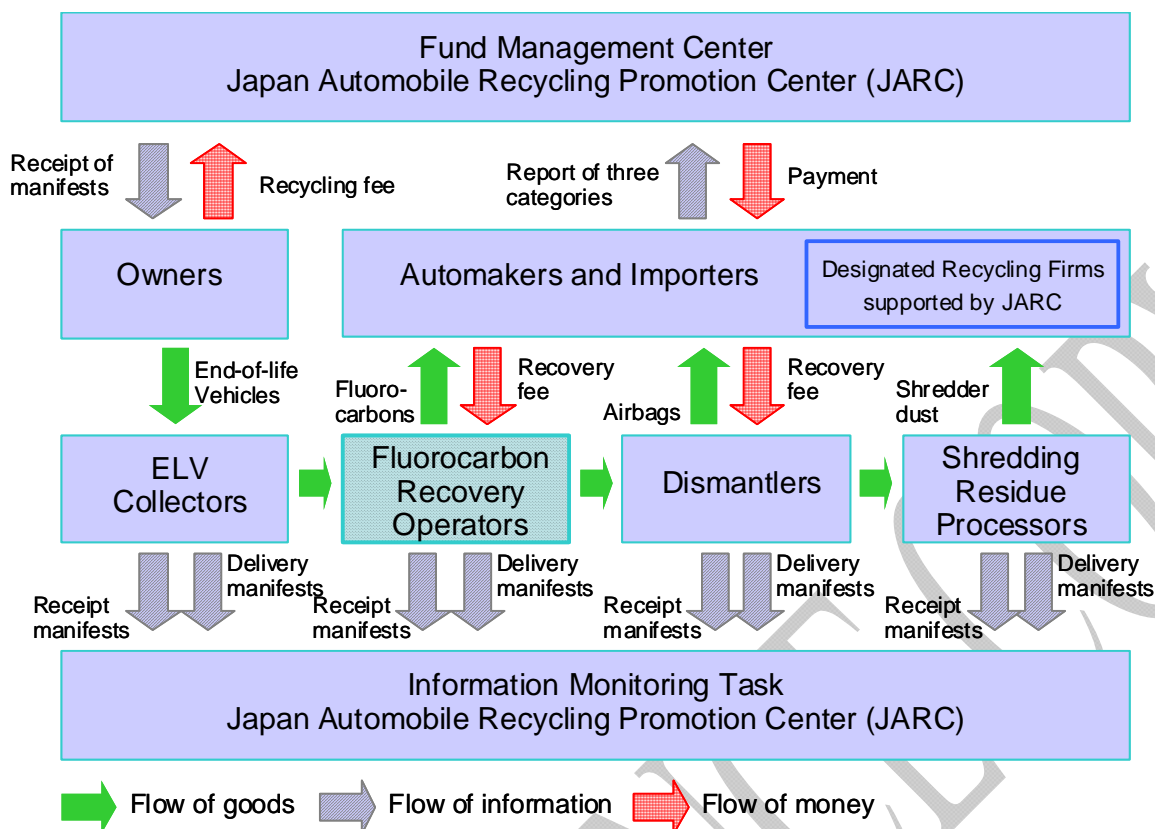


Table 5-6 and Table 5-7 are amounts of recycling and destruction of fluorocarbons in MAC. Firstly, both tables indicate that the recycling and destruction has been enforced by the Act in January, 2005. Secondly, it is seen that HFC gradually increased while CFC decreased. Finally, almost all fluorocarbons recovered are going to destruction, and only small quantities of fluorocarbons are recycled to use.

**Table 5-6: Recovery of Fluorocarbons in Mobile Air-conditioners (unit: kg)**

Fiscal year (April to next year's March)	2002 <sup>a)</sup>	2003	2004	2005	2006	2007	2008
CFC		415,169	345,818	303,936	253,842	191,731	132,713.8
HFC		222,688	290,807	399,603	523,512	617,281	702,155.0
Total	389,220	637,857	636,624	703,539	777,354	809,012	834,868.9

a) amount recovered in six months

**Table 5-7: Destruction of Fluorocarbons in Mobile Air-conditioners (unit: kg)<sup>1)</sup>**

Fiscal year (April to next year's March)	2001 <sup>a)</sup>	2002 <sup>b)</sup>	2003	2004	2005	2006	2007	2008
CFC	129,000	97,387	262,507	235,033	299,906	252,226	191,859	127,968
HFC	24,000	39,145	151,201	221,016	392,938	519,926	617,853	707,348
Total	153,000	136,533	413,708	456,048	692,844	772,152	809,711	835,316

a) Estimated values.

b) Values are for a half year

### **5.3.4 Commercial/Industrial Refrigerators and Stationary Air-conditioners**

Although the Fluorocarbons Recovery and Destruction Law was enacted in April 1, 2002, it was amended in October 1, 2007 to enforce the recovery and destruction of fluorocarbons in commercial/industrial refrigerators and air-conditioning units. Major amendments were introduction of process management, mandate of fluorocarbon recovery at maintenance operations. The process management is performed by reporting documents such as manifests, requests, confirmation, and so forth.

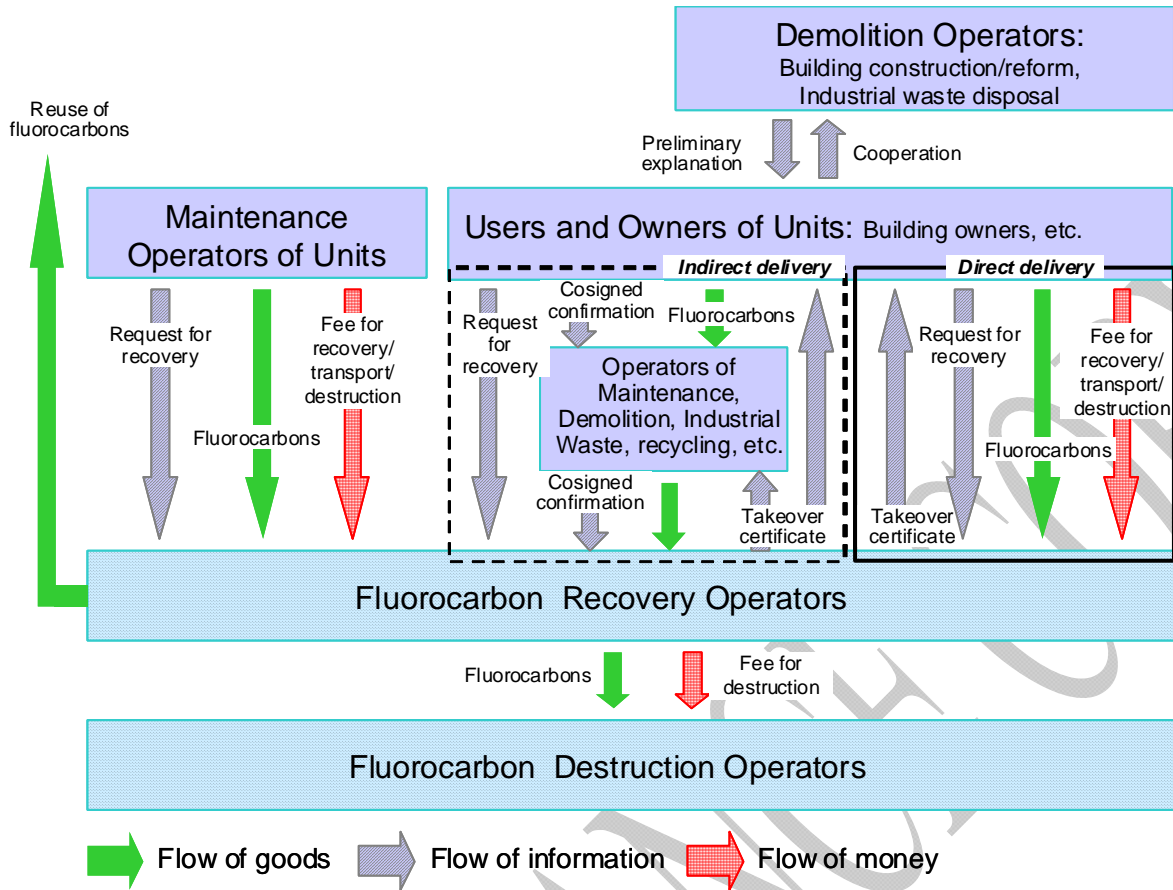
A variety of commercial/industrial refrigerators and stationary air-conditioners are installed and the operations of them are related to many persons and organisations such as users, owners, maintenance operators, demolition operators, as shown in Figure 5-8. The number of the fluorocarbon recovery operators is 29,728 and they are registered to prefectural governments. The number of fluorocarbon destruction operators is 78 and they are registered to the Government of Japan. In addition, the Japan Refrigeration and Air Conditioning Industry Association (JRAIA) and the Refrigerants Recycling Promotion and Technology Center (RRK) cooperates the recycling and destruction.

Table 5-8 is the recovery of fluorocarbons. Since the recovery value of 3,168 tonnes in 2007 included 894 thousands tonnes of recovered at maintenance operations, the recovery at maintenance operations as well as at disposal operations should be taken into account. The amounts of the destruction (Table 5.9) almost agree with those of the recovery.

Prices of the recovery operations are unclear, since commercial/industrial refrigerators and stationary air-conditioners are various sizes, and the recovery operations are, therefore, not uniform. Price for the destruction on acceptance of fluorocarbons is in the range of US\$ 3 – 6 (300 yen to 600 yen/kg).



**Figure 5-8: Flow Diagram of Commercial/Industrial Refrigerators and Air-conditioners**



**Table 5-8: Recovery of Fluorocarbons in Commercial/Industrial Refrigerators and Stationary Air-conditioners (unit: kg)**

Fiscal year (April to next year's March)	2001 <sup>a)</sup>	2002	2003	2004	2005	2006	2007 <sup>b)</sup>
CFC	317,000	387,313	337,740	297,567	291,541	348,273	342,351
HCFC	908,000	1,505,267	1,457,827	1,665,282	1,823,362	1,986,577	2,404,315
HFC		65,650	93,654	139,605	182,868	206,307	421,691
Total	1,268,000	1,958,230	1,889,221	2,102,454	2,297,771	2,541,157	3,168,357

a) Estimated values.

b) Values include the recovery at maintenance operations in addition to those at disposal operations.

**Table 5-9: Destruction of Fluorocarbons in Commercial/Industrial Refrigerators and Stationary Air-conditioners (unit: kg)**

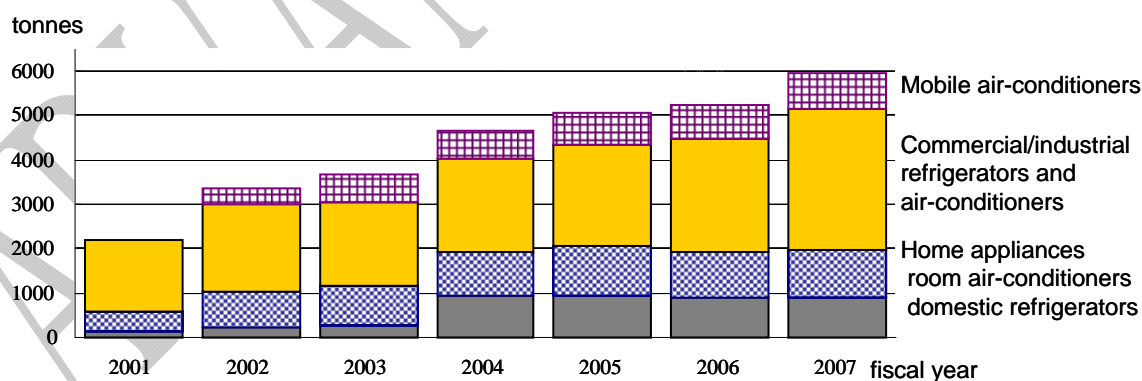
Fiscal year (April to next year's March)	2002	2003	2004	2005	2006	2007	2008
CFC	263,826	263,767	718,578	257,376	337,005	291,004	248,975
HCFC	1,225,466	1,173,124	1,575,308	1,635,545	1,839,739	2,116,920	2,419,287
HFC	89,714	71,727	195,901	215,005	252,762	426,314	641,203
Total	1,579,006	1,508,617	2,489,787	2,107,926	2,429,506	2,834,237	3,309,466

### 5.3.5 Trends of Recovery and Destruction in Japan

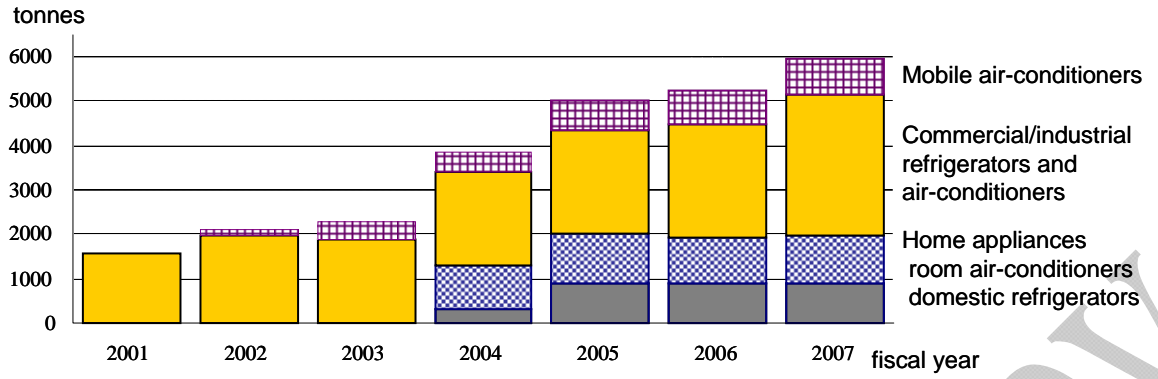
Figure 5-9 and Figure 5-10 summarise annual amounts of fluorocarbons recovered and destroyed. Both the recovery and destruction increases simultaneously. The reasons may be:

- Favourable cooperation of relevant industrial associations
- High national concern of with environmental problems
- Regional associations, such as Chlorofluorocarbon Recovery Promotion Conferences in prefectural government level
- Merging of industrial waste disposal with fluorocarbon disposal

**Figure 5-9: Annual Amounts of Fluorocarbons Recovered**



**Figure 5-10: Annual Amounts of Fluorocarbons Destroyed**



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## 6 Required Investments and Timing

### 6.1 Types of Bank Available for Recovery

Table 3-1 provides an overview of the various sources of ODS within banks in products and equipment. However, although this provides sectoral information, the table does not provide information on the status or form of material that may have already found its way into the waste stream, but is still awaiting further action. This may have arisen for a number of reasons:

- Illegal imports that have been intercepted
- Equipment previously decommissioned but ODS awaiting shipment to a destruction facility
- Unwanted stocks of ODS which are contaminated and unsuitable for reclaim or recycling

In all cases, these materials are available for destruction, but the logistics need to be assessed based on any constraints that may exist. The Expert Workshop and Report conducted in 2006 for the UN Multilateral Fund Secretariat (*ExCom 48/42*) estimated Unwanted Stocks of ODS awaiting destruction at less than 750 tonnes in 2005. Against an anticipated CFC material flow for 2010 of 25,000-30,000 tonnes and an HCFC material flow of ~150,000 tonnes (see Figure 3-1), the challenge of managing these specific unwanted stockpiles should not be too onerous provided that facilities are available within reasonable shipping distances.

### 6.2 Relationship between Low and Medium Effort Categories

The allocations set out in Table 3-1 have been used to determine the ODS banks that are considered low effort, medium effort and high effort. As already stated in the Phase 1 Report, the approach adopted has been to assume that only the low and medium effort banks can be targeted technically and economically at this stage. However, it is important to recognise that levels of effort relate to relative cost effectiveness within a sector and that recovery of medium effort ODS banks in one sector might still be more cost-effective than low effort ODS banks in another sector.

The approach taken in this Report has been to assess the bank management opportunities in terms of the approaches that would be needed to address the waste stream arisings. Accordingly, the 'Appliances and Foams' waste stream is seen to lead to the potential management of dilute sources either by mechanical processing and re-concentration, or by direct incineration. In contrast, the 'Other Refrigerant' waste stream is assumed to lead directly to concentrated arisings which can be further consolidated and shipped directly for destruction. Section 6.4 provides an indication the likely costs associated with these steps.

### 6.3 Peak Flows of ODS and Capacity Requirements

As noted throughout this Report, there are two possible approaches to the management of banks. These are:

- Management of ODS banks in isolation
- Management of all refrigerant and blowing agent banks irrespective of substance type

An assessment of the data behind Figure 3-3 covering both low and medium effort banks reveals that the flow of ODS in the 2010-2030 period is likely to reach its peak in 2016 at fractionally over 200,000 tonnes globally. The demand will switch progressively from developed countries to developing countries during the same period, with the peak in developing countries reaching 133,000 tonnes in 2020.

This type of analysis can be extended to provide information on capacity needs for both ODS and ODS Substitutes. Table 6-1 summarises these requirements:

**Table 6-1: Peak Destruction Requirements by Scenario**

	<i>Developed</i>			<i>Developing</i>		
	<i>Low</i> <i>(tonnes/yr)</i>	<i>Low/Medium</i> <i>(tonnes/yr)</i>	<i>Peak</i> <i>(yr)</i>	<i>Low</i> <i>(tonnes/yr)</i>	<i>Low/Medium</i> <i>(tonnes/yr)</i>	<i>Peak</i> <i>(yr)</i>
ODS Only	68,000	90,000	2010	61,000	133,000	2020
ODS and ODS Substitutes	160,000	215,000	2030	110,000	220,000	2030

Estimates of current global capacity vary significantly. The TEAP Task Force's current estimates suggest that there are over 150 ODS destruction facilities worldwide, although less than 10% of these are believed to be situated in developing countries. Table 6-2 provides an updated version of the distribution table contained in the Phase 1 Report.

The stated capacities of these facilities vary widely and it appears that the method of assessing and quoting capacity is not standardised across the industry. ICF, as part of its assessment of ODS Bank Management strategies for the European Commission is estimating destruction capacity within the EU-27 of 145,000 – 260,000 tonnes. The US is understood to have a similar capacity available for handling ODS. This would tend to suggest that, on a global basis, there would be sufficient destruction capacity to deal with the annual arisings from Table 6-1, even when both low and medium effort banks are being managed and both ODS and ODS substitutes are targeted.

**Table 6-2: Location of ODS Destruction Facilities currently in Operation**

<b>Country</b>	<b>Number of Known ODS Destruction Facilities in Operation</b>
1. Australia	1
2. Austria	1
3. Belgium	2
4. Brazil	6
5. Canada	2
6. China	10
7. Czech Republic	1
8. Denmark	3
9. Estonia	1
10. Finland	1
11. France	2
12. Germany	7
13. Hungary	5
14. Indonesia	1
15. Italy	12
16. Japan	75
17. Jordan	2
18. Mexico	2
19. Netherlands	6
20. Poland	1
21. Republic of Korea	1
22. Russian Federation	3
23. Slovakia	1
24. Spain	1
25. Sweden	4
26. Switzerland	> 4
27. United Kingdom	5
28. United States of America	< 10

It is important to recognise that ODS destruction does not operate in isolation. There are a large number of facilities operating globally for the destruction of PCBs – a number of which are jointly used for ODS and PCB destruction. A catalogue of these PCB destruction facilities has been published by UNEP-DTIE and may contribute to the overall capacity available for ODS destruction. However, while the PCB capacity is available and is technically capable of ODS destruction (minimum 99.99%), it is important to note that there is currently a backlog of 1.7 million tonnes of PCBs awaiting destruction globally and therefore available capacity is likely to remain at a premium for the foreseeable future.

In addition, large-scale destruction of ODS on any PCB facility will require protection of the equipment against the corrosive attack from fluorine.

In conclusion, the ODS and ODS Substitute material flows requiring management are not substantially out of scope for the existing destruction capacity. The ability to use PCB facilities in addition to dedicated ODS facilities could assist some of

the logistics challenges. However, a more in depth study of the precise locations is required to assess the need for additional capacity. This was viewed as beyond the scope of this Report in the time available. However, it is clearly a requirement if this agenda is to be pursued more fully.

#### **6.4 Costs Associated with Recovery of Low/Medium Effort Banks and likely Timing**

The costs assembled within the Phase 1 Report were of a preliminary nature and attracted a significant number of questions. One of the reasons for this was the lack of transparency created by the combining of Transport Costs for both the Recovery and Destruction steps. It was also recognised that further transparency would be helpful with respect to Recovery Processing Costs and specific Destruction Costs. To this end, Table 6-3 has been created to provide greater insight into the basis for the overall cost estimates that follow for low and medium effort banks.



**Table 6-3: Components of Cost relating to Recovery and Destruction Steps (\$ per kg ODS)**

<i>Effort Level</i>	<i>Sector</i>	<i>Population Density</i>	<i>ODS Recovered</i>	<i>Segregation/Collection Costs</i>	<i>Transport Costs (Recovery)</i>	<i>Recovery Processing Costs</i>	<i>Transport Costs (Destruction)</i>	<i>Destruction Costs</i>	<i>Total Cost</i>
				(US\$ per kg)	(US\$ per kg)	(US\$ per kg)	(US\$ per kg)	(US\$ per kg)	(US\$ per kg)
<b>Low Effort</b>	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		46-64	
	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	
<b>Medium Effort</b>	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

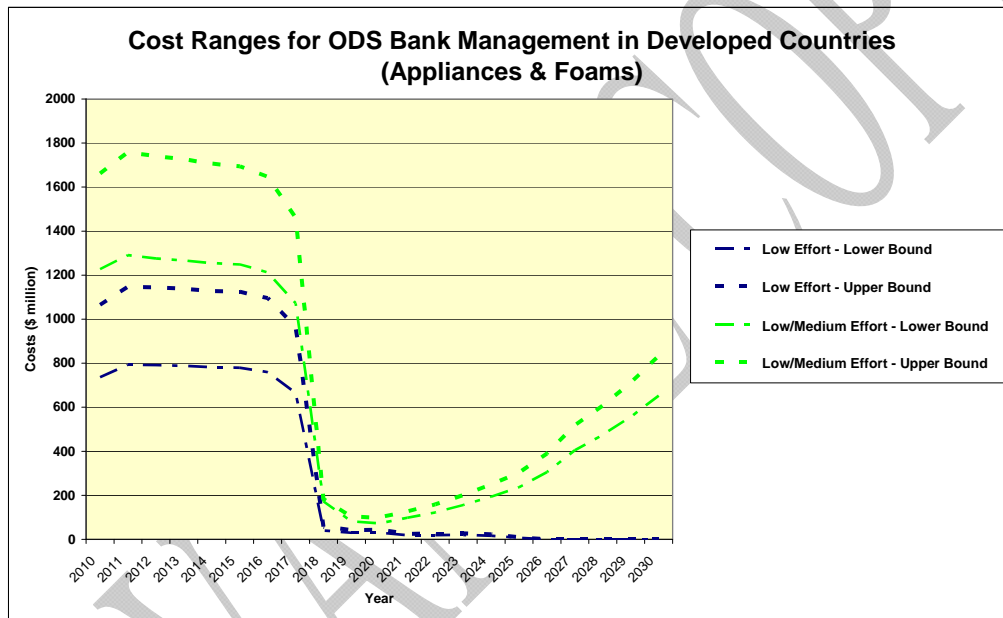
^^^ Shipping complete units

Using this table, it is possible to combine the cost data per kg of ODS destroyed with the material flow assessments highlighted in Sections 3 and 4 in order to provide first order estimates for ODS recovery and destruction on an annualised basis. This approach provides ranges of cost and the data is therefore presented with upper and lower bounds.

Appliances and Foams

Dealing with the costs for the management of ODS recovery and destruction in Appliances and Foams first, the following two graphs indicate the situation in developed and developing countries:

**Figure 6-1: Trends in cost for Low and Low/Medium Effort Appliances and Foams for ODS only (Developed Countries)**



**Figure. 6-2: Trends in cost for Low and Low/Medium Effort Appliances and Foams for ODS only (Developing Countries)**

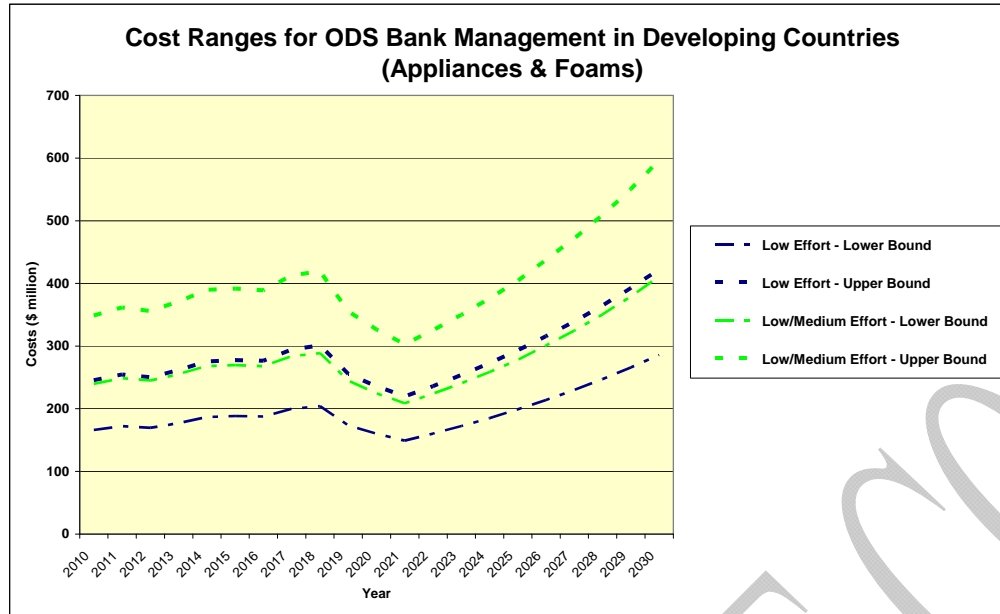
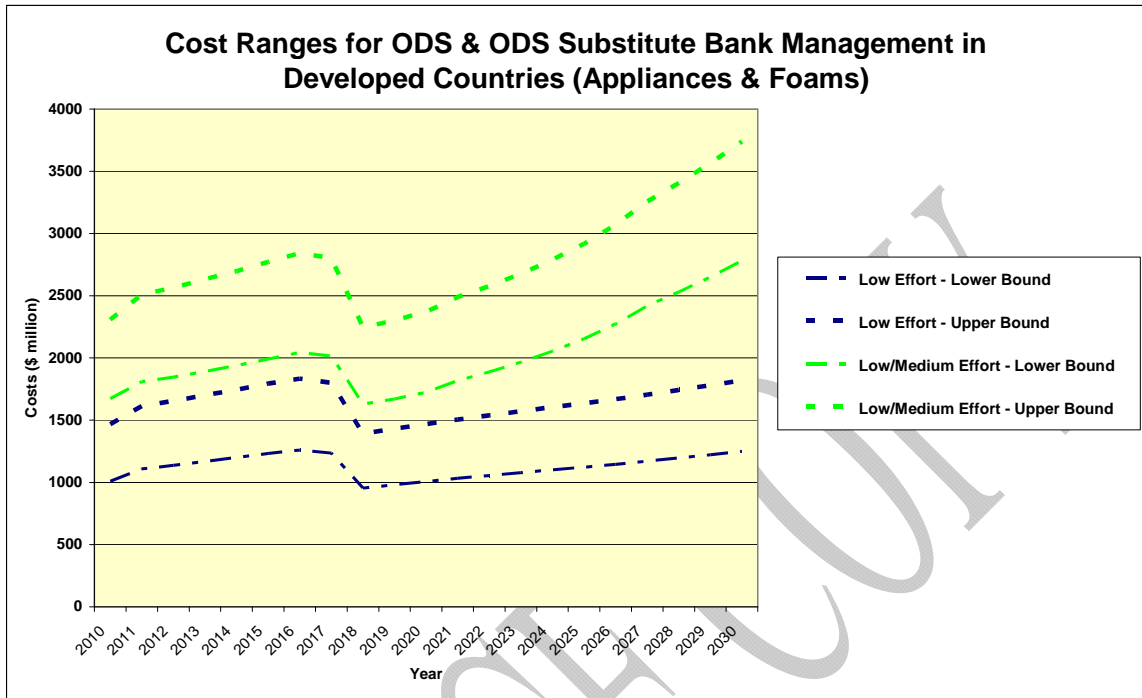


Figure 6-1 confirms that costs as high as US\$ 1.6-1.8 billion annually would need to be covered – primarily for appliance - up until the point of HCFC-141b-based foams reduce in the waste streams in around 2020. The costs of ODS recovery and destruction only then begin to raise again when ODS contained in foams in buildings begin to grow in the waste stream. Based on a 50 year building life assumption, this is in the post-2020 period. However, it could be sooner in building types that are either replaced or refurbished more frequently. These are reflected in the medium-effort trends shown in Figure 6-1.

Figure 6-2 shows that the cost of refrigerator management in developing countries could be lower on an annualised basis but the period over which ODS management will be necessary could be considerably longer, based on the fact that many appliances are still being manufactured using HCFCs as foam blowing agents at this time. The step in the graphs in Figure 6-2 reflects the adoption of low-CFC formulations in many developing countries (see Section 5.2).

Figure 6-3, below reveals that the costs for including ODS Substitutes in the strategies for managing Appliances and Foams in developed countries could be significant:

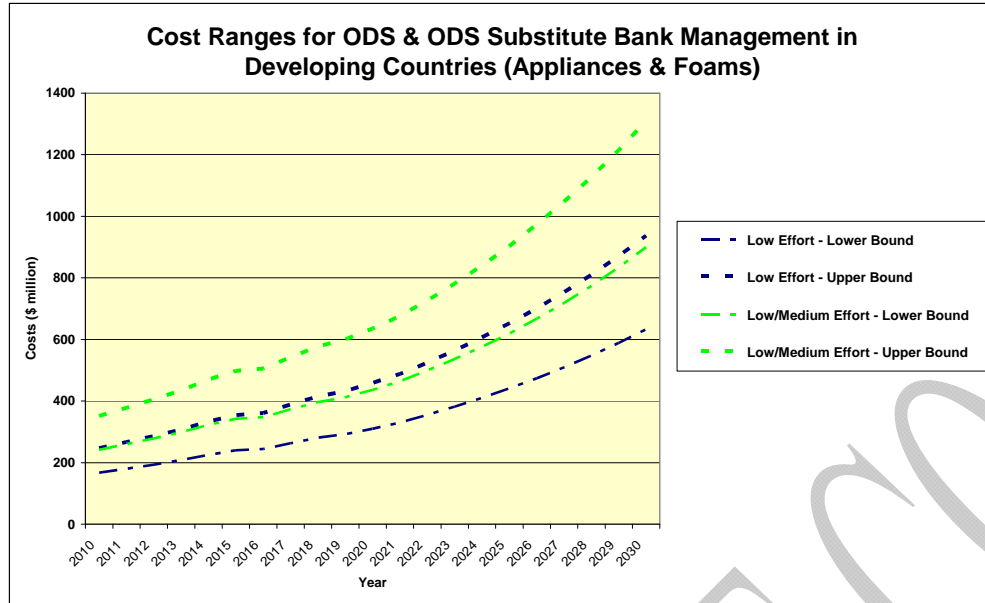
*Figure. 6-3: Trends in cost for Low and Low/Medium Effort Appliances and Foams for both ODS and ODS Substitutes (Developed Countries)*



In this instance, the step in the curves arises from the better blowing efficiencies of both hydrocarbon and HFC technologies and the resulting lower concentrations in the respective foams. It should be noted that the overall cost of bank management has increased significantly overall, even in the early years, because of the inclusion of hydrocarbon containing appliances which were introduced in Europe and Japan as long ago as the early 1990s.

For developing countries the inclusion of ODS Substitutes is less dramatic until the latter years of the period under study when the costs of managing the refrigerators that converted directly from CFCs to hydrocarbons really begins to emerge, as shown in Figure 6-4 below:

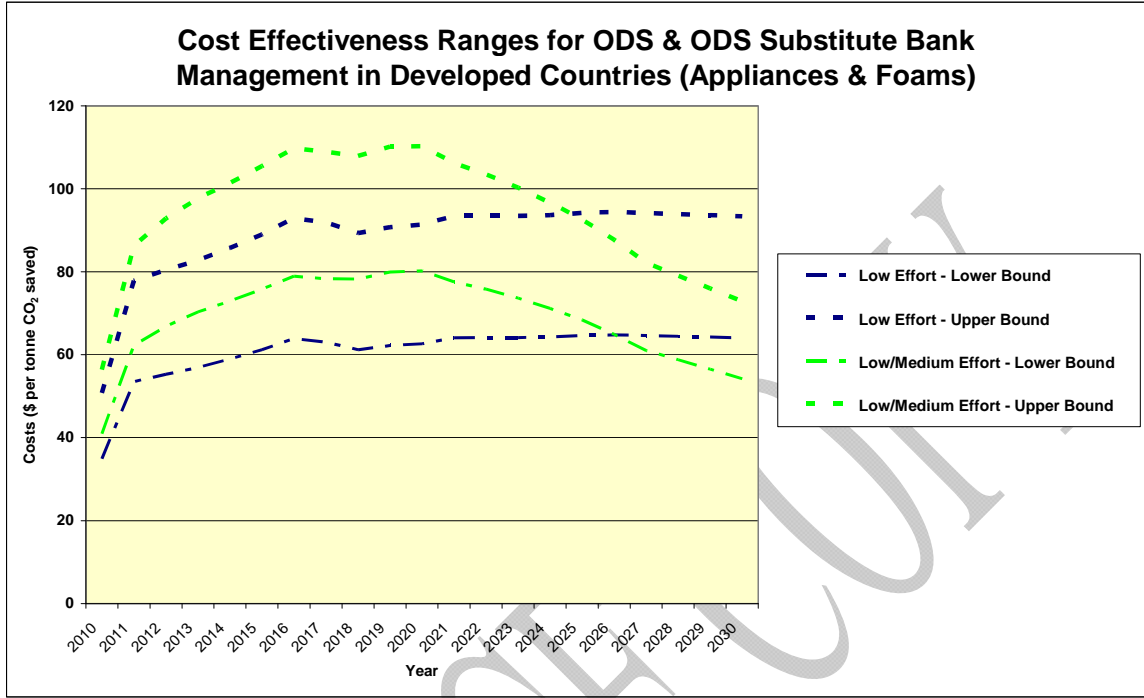
**Figure 6-4: Trends in cost for Low and Low/Medium Effort Appliances and Foams for both ODS and ODS Substitutes (Developing Countries)**



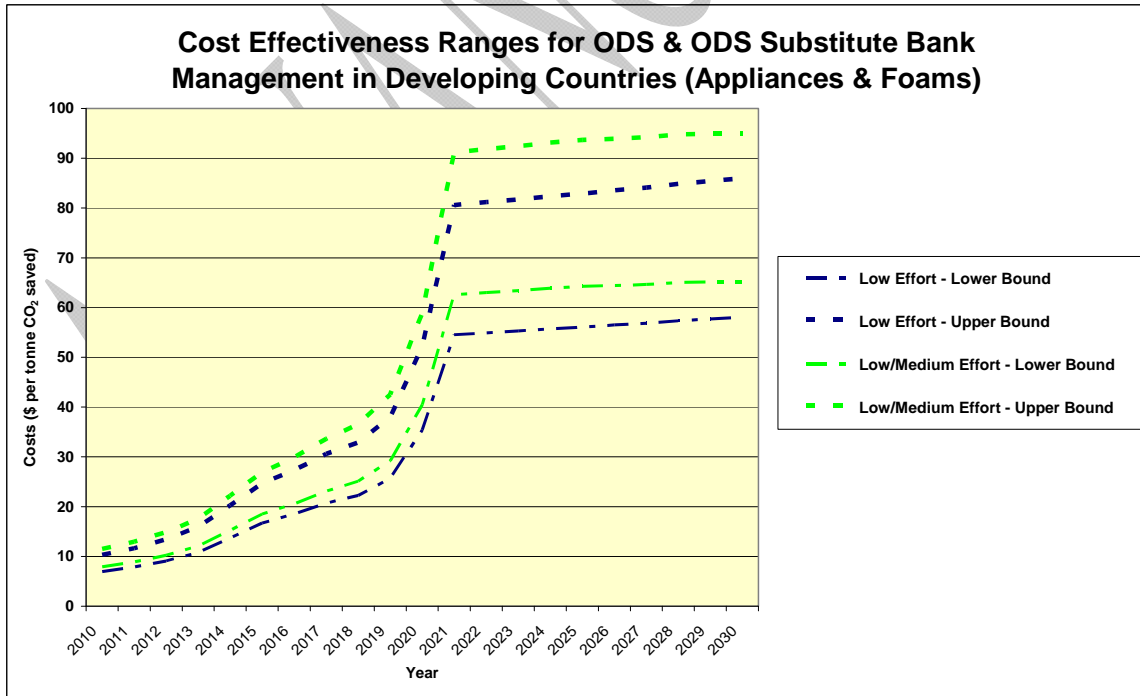
Where decisions are taken to manage the whole portfolio of ‘Appliances and Foams’ available in the low and medium effort categories, the cost effectiveness of that management in climate terms will be largely driven by the mix of refrigerants and blowing agents managed. Figure 6-5 shows how the cost per tonne of CO<sub>2</sub>-eq. saved will increase rapidly in the period to 2015 as the proportion of CFCs in the product mix decreases. At its peak, the cost of managing ODS and ODS Substitutes Banks could reach US\$ 100-120 per tonne of CO<sub>2</sub>-eq. saved, reflecting a period when appliances will largely be HCFC and hydrocarbon blown and little CFC will have reached the waste stream from CFCs contained in building foams. It is interesting to note the impact on cost effectiveness of the growing level of CFC from that source in the mix in the combined low/medium effort plots in the post 2020 period.

For developing countries, the trends are rather different, as shown in Figure 6-6, where the absence of significant building foams means that the cost per tonne of CO<sub>2</sub> saved continue to increase with time. The major step, of course, reflects the transition from CFCs to HCFCs in the waste stream. However, it is noteworthy that the peak cost stays below US\$ 100 per tonne of CO<sub>2</sub> saved in this instance.

**Figure 6-5: Trends in cost effectiveness for Low and Low/Medium Effort Appliances and Foams for both ODS and ODS Substitutes (Developed Countries)**



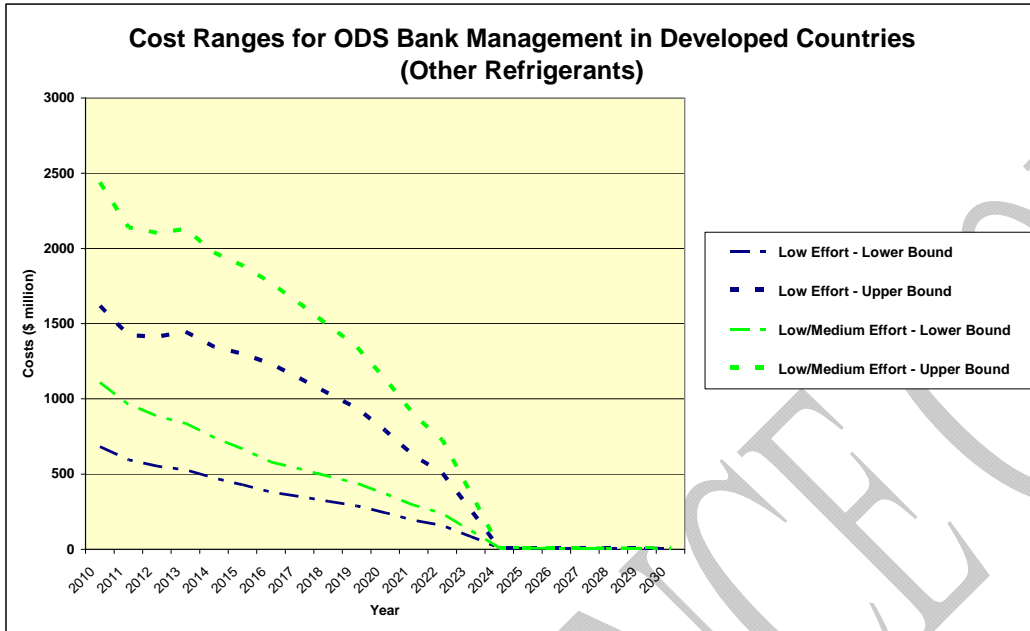
**Figure 6-6: Trends in cost effectiveness for Low and Low/Medium Effort Appliances and Foams for both ODS and ODS Substitutes (Developing Countries)**



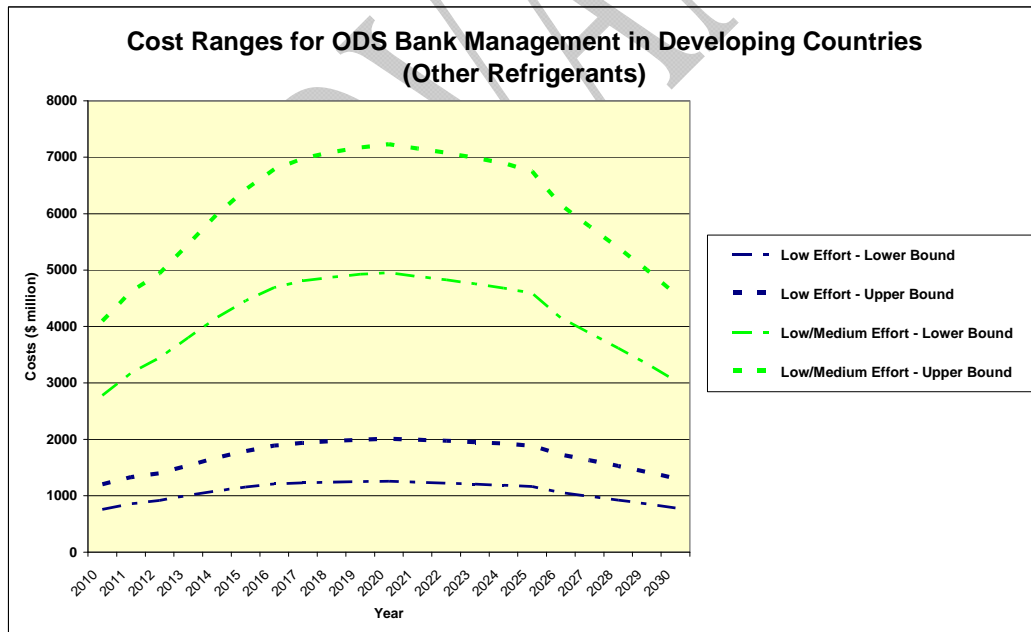
Other Refrigerants

Similar analyses can be applied to the management of Other Refrigerants as shown below for developed and developing countries when managing ODS only.

**Figure 6-7: Trends in cost for Low and Low/Medium Effort Other Refrigerants for ODS only (Developed Countries)**



**Figure 6-8: Trends in cost for Low and Low/Medium Effort Other Refrigerants for ODS only (Developing Countries)**

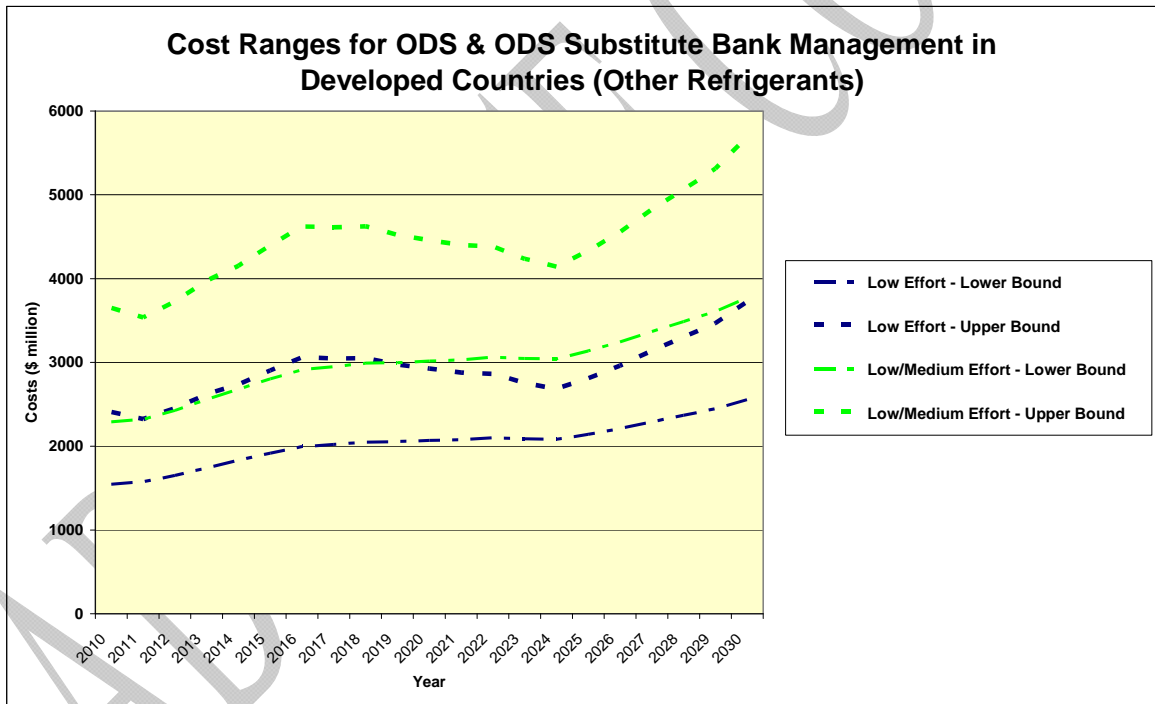


Figures 6-7 and 6-8 reveal the contrast between ODS refrigerant management strategies between developed and developing countries. Since ODS-containing refrigerants are already in decline in developed countries and their lifetime in use is relatively short, the costs of bank management do not exceed US\$ 2.5 billion annually, even when including those in sparsely populated regions.

For developing countries, the proportion of ODS refrigerant in sparsely populated regions is higher and leads to a greater cost burden for collection. Accordingly, it is estimated that US\$ 7-8 billion annually would be required during the peak years between 2018 and 2024 to recovery these refrigerants.

When consideration is given to the management of both ODS and ODS Substitutes, the developed country situation changes significant, as shown in Figure 6-9:

**Figure 6-9: Trends in cost for Low and Low/Medium Effort Other Refrigerants for ODS and ODS Substitutes (Developed Countries)**

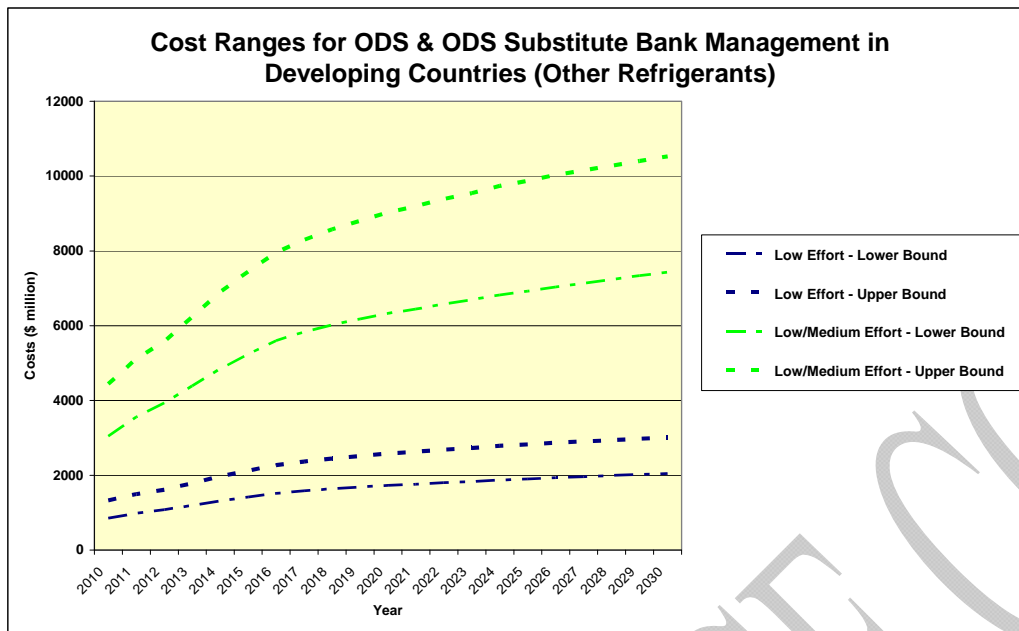


In this instance, the growth in cost related to the inclusion of ODS Substitutes might appear excessive but, as is made clear later in this Section, the climate value of on-going ODS Substitute management is significantly greater than for domestic appliances and foams.

For developing countries there is a similar growth trend in cost, with levels potentially reaching as high as US\$ 10 billion annually in 2030, as shown in Figure 6-10.

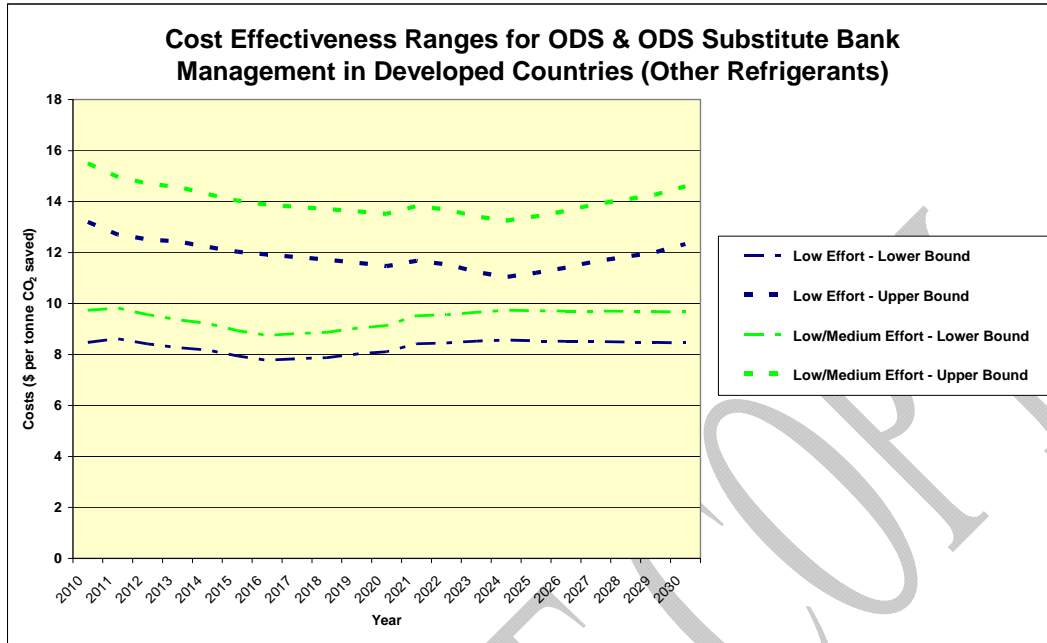


**Figure 6-10: Trends in cost for Low and Low/Medium Effort Other Refrigerants for ODS and ODS Substitutes (Developing Countries)**



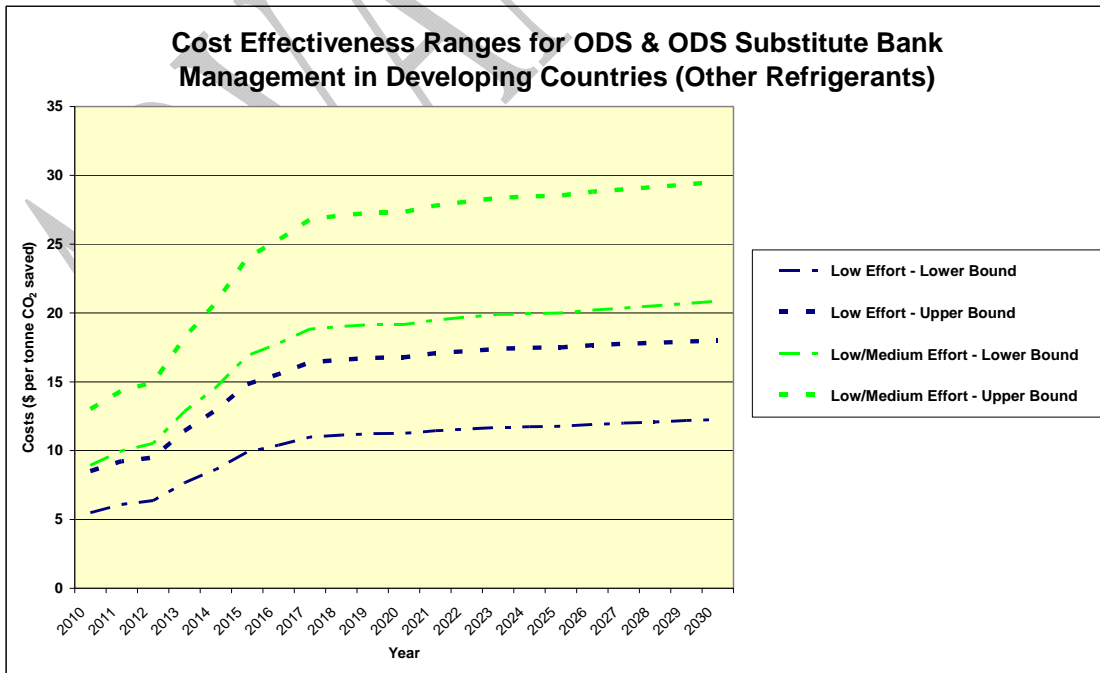
Despite the fact that the combined cost of managing Other Refrigerants globally could reach in excess of US\$ 15 billion annually by 2030, the significant difference for this category of ODS and ODS Substitute bank is that the cost effectiveness is both more attractive and more consistent than for Appliances and Foams. This is shown for developed countries in Figure 6-11:

**Figure 6-11: Trends in cost effectiveness for Low and Low/Medium Effort Other Refrigerants for ODS and ODS Substitutes (Developed Countries)**



For developing countries there is a similar story based on the on-going capture of HCFC-22 and its replacements. However, in this instance there is an early increase in cost per tonne of CO<sub>2</sub> saved resulting from the on-going reductions in the CFC content of the average substance mix reaching the waste stream (Figure 3-9 refers):

**Figure 6-12: Trends in cost effectiveness for Low and Low/Medium Effort Other Refrigerants for ODS and ODS Substitutes (Developing Countries)**



In summary, the Phase 1 Report highlighted average costs of abatement for low effort banks of approximately US\$ 15 per tonne of CO<sub>2</sub> saved, while low/medium effort banks combined would require investment in excess of US\$ 35 per tonne of CO<sub>2</sub> saved. This further analysis provides additional information on how these costs might vary by product sector, region and in time.

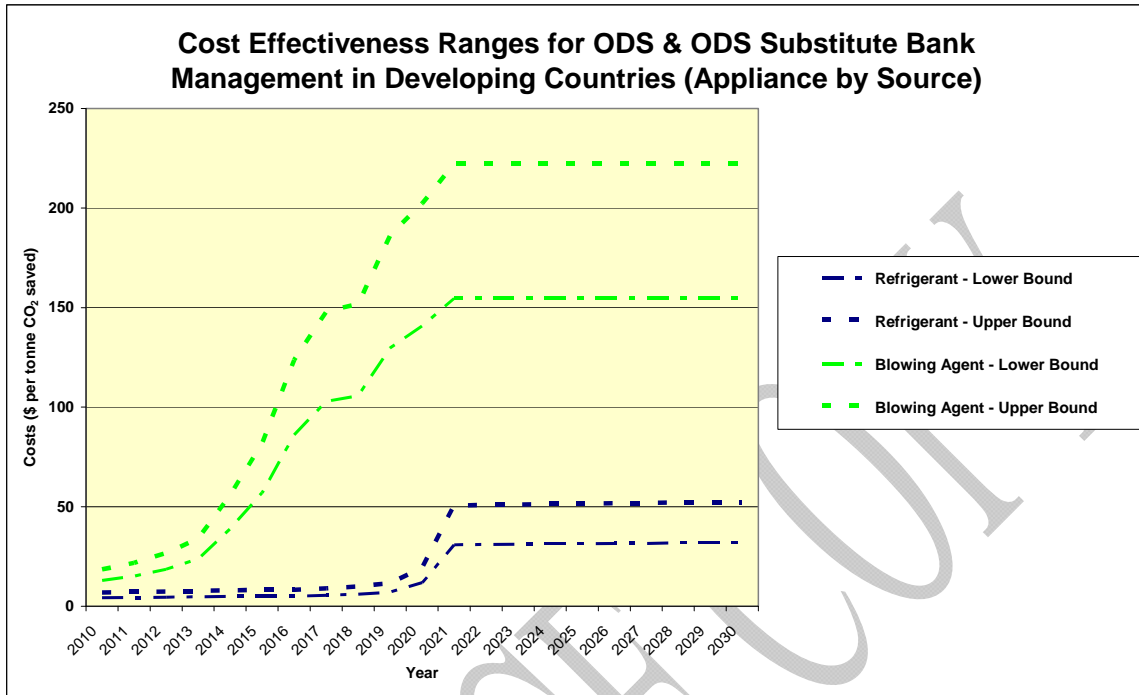
#### *Specific Cost issues for Domestic Refrigerators*

There is a further question surrounding the inclusion of refrigerants from domestic refrigerators within the Appliance and Foams Sector since decisions to avoid this sector because of the high average costs related to climate benefits might result in the loss of relatively cost-effective opportunities. This is most likely to be the case in developing countries where considerable use of CFC-12 continues in an ageing domestic refrigerator stock. As noted in Section 5.2, Brazil alone may have over 17.6 M tonnes CO<sub>2</sub>-eq. of CFCs in its refrigerator stock of which 13.7 M tonnes CO<sub>2</sub>-eq. will be related to CFC-12 at a global warming potential of 10,720.

With this in mind, there could be a strong justification for recovering refrigerants from domestic refrigerators even when the overall cost of total ODS bank management (i.e. blowing agents as well as refrigerants) might be prohibitive.

In its current form, Table 6-3 lists the costs of managing the refrigerant on the basis that the equipment is brought to a centralized point and de-gassed. This is typically described as a Stage 1 process in refrigerator recycling terms. It can be seen that overall costs are not substantially different for recovery of 'refrigerant only' than for refrigerant and foam blowing agent. This reflects the fact that there is more blowing agent than refrigerant to recover per unit. Additionally, in the 'refrigerant only' case, the investment would be spread over a lower overall ODS recovery and ultimate destruction. Nevertheless, the cost effectiveness of refrigerant recovery is likely to become progressively more comparatively attractive over time because of the higher GWPs associated CFC-12 replacements than with CFC-11, replacements. Figure 6-13 below, shows a more detailed review of these cost trends with time for developing countries only:

*Figure 6-13: Trends in average cost effectiveness for Refrigerants and Blowing Agents for ODS and ODS Substitutes (Developing Countries)*



The graph clearly makes the case that the management of refrigerants in isolation from blowing agents could be a relevant strategy over time in developing countries, largely because of the higher average global warming potentials associated with CFC-12 and HFC-134a.

An even more cost-effective route might be the use of a portable de-gassing facility, but experience in Europe and elsewhere found that recovery rates are highly sensitive to ambient temperatures. In addition, throughput rates are generally slower.

### 6.5 Investment Thresholds for Recovery and Destruction Facilities

Table 6-1 already suggests that the global demand potentially arising from total ODS bank destruction will peak at no more than 225,000 tonnes per annum, and likely considerably less. Based on the information already set out in Section 6.3 on likely capacity in Europe and North America it seems likely that no investment will be likely in destruction capacity. This assessment comes even before the consideration of developing country capacity in Brazil, Indonesia and elsewhere.

For recovery facilities, however, the investment thresholds may become a more significant factor. Continuing from the previous section on appliance management

Table 6-4 below summarises the likely investment required to potentially manage refrigerants and foams.

**Table 6-4: Likely Investment Costs for Refrigerator Recycling Equipment**

<i>ODS Managed</i>	<i>Equipment Type</i>	<i>Investment</i> (US\$ ,000)	<i>Throughput</i> (‘000/yr)	<i>ODS Quantity</i> (tonnes/yr)
Refrigerant Only	Stage 1	250-400	250-350	40-50
Refrigerant + BA	Stage 1 + Manual	600-1,000	150-200	50-70
Refrigerant + BA	Stage 1 + Stage 2	4,000-6,000	200-400	65-130

According to the information prepared for this Report, the peak flow of CFC-12 into the waste stream from domestic refrigerators would occur in 2016 at around 4,750 tonnes per annum. On the basis of Table 6-4, this would require 100-120 Stage 1 units at an overall cost of approximately US\$ 25-50 million. However, the number of facilities required would continue to increase to 150 and beyond if the HFC-134a replacing CFC-12 was also to be managed.

Clearly, investments to manage foams additionally would be significantly higher, although the adoption of a manual route, providing that it can meet adequate performance standards related to losses during handling could be an opportunity in some more significant conurbations. A full investment in Stage 1 + Stage 2 facilities could also be contemplated, but value of the investment would need to be largely recovered prior to 2020 when the levels of CFC in the waste stream will reduce significantly.

For the collection and recovery of Other Refrigerants, the picture varies depending on the sector involved and whether recovery is affected on-site or at a centralised facility (similar to the Stage 1 facility envisaged for domestic refrigerators). Adopting this approach, investments for stationary air conditioners alone could be up to 5-10 times higher than for domestic refrigerators in order to deal with a peak flow of approximately 35,000 tonnes of HCFC-22 per annum in 2025.

Although beyond the scope of this Report, it is likely that there is a wealth of information on costs of recovery of refrigerants established from the various refrigerant management plans implemented over the last ten years. It might be useful to initiate a further systematic investigation into this source data.

## **6.6 Logistical Challenges**

### **6.6.1 Locating and Securing Products and Equipment**

Since there is no universal database of refrigeration equipment, any action to segregate refrigeration equipment needs to be triggered on entry into the waste stream.

For the domestic refrigerator sector there can be three main points of interception. These are:

- The retailer of new equipment offering a ‘take-back’ scheme
- Curb-side collections offered by private contractors or local authorities. In the case of private contractors, there needs to be an incentive which would be generated either by the recycled value of the metals or any bounty placed on the recovery of ODS.
- Collection at central municipal waste facilities with individual owners delivering their refrigerators for disposal.

In practice, each of these methods has been shown to work effectively, but the choice depends on the societal custom and practice.

For other types of refrigeration equipment, the location is more likely to be at a private or public enterprise. In this instance, legal structures can be put in place to ensure that appropriate end-of-life policies are followed. Where large (industrial) facilities are known to exist the individual owners can be targeted and, in the case of national supermarket chains (commercial refrigeration), the corporate structures can be used to cascade instructions on end-of-life management.

For mobile air conditioning systems, relevant vehicle end-of-life legislation is necessary to identify and capture the remaining charge of ODS in a scrapped vehicle. Governments need to ensure that appropriate text exists in any relevant legislation put in place. Nevertheless, charge losses are highly likely in this sector prior to the vehicle reaching the appropriate management point.

For buildings, except those under Government control, communicating and policing the procedures for end-of-life management of ODS banks is difficult. Some countries have relatively advanced requirements that require any significant demolition project to carry out an environmental survey for hazardous substances. This should capture the presence of ODS-containing foam provided that access is available to check with a suitable detector.

However, where identification of the foam prior to demolition does not occur, the challenges of later segregation can be significant. Although, in some regions, the foam qualifies as hazardous waste when separated, the need to divert the foam to a hazardous waste landfill is often avoided, since the mixed demolition waste in which the foam often resides does not trigger the threshold concentration.

### **6.6.2 Enforcement Considerations**

Several regions and countries have now had significant experience of managing products and equipment containing ODS at end-of-life. As noted in Section 5.1, the European Union has struggled to achieve consistent implementation and enforcement of the ozone regulation EC2037/2000 across its Member States. The

concern over enforcement is likely to deepen if efforts are made to broaden the range of products and equipment covered by the legislation.

In Japan concerns have been voiced about the efficacy and cost of enforcement. This becomes particularly challenging in areas where there may be some uncertainty about the technical feasibility of recovery practices. In 2002, the Japanese Government investigated the possibility of legislating the recovery of ODS from foams in buildings but, after a three year research study by the Japanese Technical Centre for Construction Materials (JTCCM) concluded that a voluntary incentive-based programme would be more appropriate.

### **6.6.3 *Distribution and Destruction Centres***

There are two consecutive processes that need to take place when ODS are recovered and destroyed. The first relates to the collection and recovery of the products and equipment containing the ODS, where this is appropriate, or the on-site removal of the ODS in other circumstances. The second relates to the removal of the ODS from the product or equipment and the transfer of the removed ODS to a destruction facility.

Table 6-3 has already considered the cost components of these transfers and the cost broadly mirrors the level of complexity posed. As a general principle it is important to minimise the shipment distances for products and equipment by having as many collection points as possible. The balance of the shipment distance to the nearest destruction facility can then be covered with the ODS in concentrated form (e.g. in bottles and cylinders). Tracking of materials collected is also important, particularly where shipping distances are long and/or transport is intermodal.

### **6.6.4 *Suitability of Existing Destruction Facilities***

This issue has been reviewed at some length in Section 6.3 for facilities seeking to destroy concentrated sources. As noted in the Phase 1 Report, the Montreal Protocol Handbook also provides significant guidance on the identity of Approved Destruction Technologies and the good practices to be adopted when shipping concentrated sources.

The situation is a little more complex for dilute sources such as insulation foams, which can be directly incinerated with energy recovery (up to 20 kWh for the foam contained in a typical refrigeration unit) in Waste to Energy facilities and Municipal Solid Waste Incinerators. However, care must be taken to limit the feed to no more than 5% in order to ensure adequate combustion and sufficiently high temperatures to ensure the destruction of ODS contained within the foams. An additional concern arises from the propensity of fluorine containing chemicals to attack combustion chamber and chimney linings. It is generally most appropriate to modify the lining materials prior to acceptance of such materials on a routine basis.

### **6.6.5 *Transport Costs related to Sparsely Populated Areas***

As noted in Section 6.6.3, the key to minimising overall transport costs is to limit the distances over which products and equipment are shipped. This can be achieved by having a large number of well-spread collection centres or, alternatively by having a mobile collection and recovery facility.

In the case of the latter, SEG has produced and marketed a mobile refrigerator recycling facility for many years. This could have particular value in some developing countries where populations are spread, but such equipment does rely on an adequate infrastructure and remote utilities that may not be available in many locations. It is clear that such strategies need to be evaluated and planned carefully to ensure that the optimum value from an investment is achieved.

Once concentrated, Table 6-3 reveals that the shipping costs associated with ODS are very modest. The challenge is more likely to be ensuring that waste ODS can be shipped legally and, in particular, passed between countries. Efforts are already underway to facilitate this approach and the United States, for one, is seeking to make the importation for destruction a practiced that will be encouraged under appropriate US EPA controls.

### **6.6.6 *Particular Transport Challenges related to Island States***

One of the major tests for Island States is that they face the combined challenge of inter-modal transport and cross-border shipment. This challenge is, of course, not limited to the management of ODS but of all hazardous wastes needing destruction. In some quarters, consideration has been given to the possibility of created a mobile destruction facility on board ship. However, the poses particular questions about the jurisdiction for destruction and the control of licences. Some thought has been given to the potential for such destruction to be handled by the military who would logically be exempt from such constraints. However, it is understood that there may yet be a number of other hurdles to jump before such a proposal becomes a reality.

### **6.6.7 *Enabling and Managing Long-Term Storage***

Since the earliest days of the Montreal Protocol, when halons and other Class I ODS were still in wide-spread production, the Halons Technical Options Committee (HTOC) recognized the need to manage the existing supplies or banks of halons as a means to reduce emissions and future production. The concept of banking or re-using existing quantities of halons instead of relying solely on new production led to the early phase-out of halons in 1994 for non-Article 5 Parties, which was two years ahead of the phase-out of CFCs. Today, banking programmes for halons around the world continue to be responsible for reducing emissions and for negating the potential for future production beyond the complete global (production) phase-out that will occur at the end of this year. Halon banking has been and remains a critical part of the management of halons.



Over the years, the HTOC has reported on the development, implementation, and operation of many successful (and some less than successful) halon banking programmes. Even so, there have been some misinterpretations or misunderstandings that may still exist today. The basic premise for successful halon banking is that there will continue to be a supply of halons to meet the needs of users who must still rely on halons for adequate fire and life safety protection for the foreseeable future. There remain long-term users for halons such as the military, civil aviation, and oil and gas production in cold climates. On the one hand, some of these long-term users have developed their own physical banks, where they own all of the halon that they project they will need for the lifetimes of their uses. The U.S. military is one example of this approach. On the other hand, there are users that have not purchased all of the quantities that they need but instead rely on the global recycled halon market only buying what they need to cover up to a few years at a time. Alaskan oil and gas production, and civil aviation are examples of this type of approach.

The global movement of recycled halons has been and remains a basic part of halon banking. Measures that eliminate or greatly restrict trans-boundary movement of recycled halons can hinder efforts to manage the existing quantities in two ways:

- 1) it may foster the need for Essential Use (production/ consumption) Exemptions to be granted if adequate supplies are not available to meet needs, per Decision IV/25  
and
- 2) it may result in increased emissions if local extreme surpluses reduce the overall local value and need to manage the local bank (i.e., the need to spend resources to keep emissions low). It must be pointed out that both of these situations could result at the same time, with large excesses in some areas or regions and extreme shortages in others. An unintended consequence of this is that it may also result in the increased need for HCFCs and/or high GWP alternatives as the only suitable alternatives to halon that provide an adequate level of fire and life safety protection for many of the above applications are HCFC, or a high GWP fire fighting agents.

Currently, the prevailing trend appears to be that more and more Parties are increasing regulatory strategies to managing halon banks as we approach full production/consumption phase-out by the end of this year. As part of this phase-out there is a growing tendency to also require mandatory decommissioning of all halons that are not in locally defined “critical uses” or in physical banks dedicated to supplying these critical uses. This is not required by the full phase-out, which is only for production and consumption, and in fact may be counter to the goal of avoiding an Essential Use (production/consumption) Exemption post 2010. The

early phase-out in non-article 5 Parties and the successful phase-down by Article 5 Parties to date was enabled through the use of recycled halons. Just as civil aviation in non-Article 5 Parties has been able to fill their needs since 1994 with global recycled halons, Article 5 Parties should be able to do the same as long as the recycled markets remain open and recycled halons are allowed to continue to be marketed. In the report on Decision XIX/16, the HTOC reported that some civil aviation experts were beginning to express concern that halon 1211 supplies would not be available to continue to support their civil aircraft over their economic lifetimes. Global estimates continue to show that adequate supplies of recycled halon 1211 should be available. What has changed is that an increasing number of Parties have eliminated import of all halons, including recycled, and other Parties have limited or completely eliminated export of recycled (or able to be recycled) halons.

Regardless of the mix of regulatory and market forces that a Party uses to manage their halon bank, the goal remains to keep halon valuable in order to minimize emissions and maximize re-use. As the long-term needs for halon decrease, there may be increasing pressure to destroy local excesses for carbon credits. This indeed could be a valuable mechanism to manage the halon bank with a positive outcome for the ozone layer and the climate system as long as a few potential pitfalls are avoided. The first pitfall would be to jeopardize fire and life safety protection with the potential short-term gains from a lucrative market for destroying halons, which have significant GWPs. The second potential pitfall would be to destroy too much halon and then have to produce it again at a later date, the so-called destruction for production scenario. The last pitfall is to cause a transition to high GWP alternatives that otherwise would not have occurred, resulting in a higher impact on the climate system than continuing to use the existing halons. It is important to make sure that the comparison is done on a system basis and not just on GWP values. For example, replacing halon 1301 with a GWP of 7060 with HFC-227ea with a GWP of 3220 does not reduce the climate impacts by as much as it may appear on the surface, because you need more than 1.6 pounds of HFC-227ea to replace one pound of halon 1301 in a protection system. The comparison becomes significantly less climate beneficial if the replacement is HFC-23. In considering the climate impacts from the destruction, the production of the alternative, the additional steel cylinders, the increased transportation emissions from the increased weight, etc., the climate benefits would be much lower than appears from direct comparison of the GWPs. For halon 1211 alternatives for civil aviation, with the exception of the HCFC-123 based blend, all of the alternatives approved to date have a higher climate impact than continuing to use existing halon 1211. Similarly, for very low temperature oil and gas production, the only alternative to halon 1301 is HFC-23, which has a higher GWP than halon 1301 as well as requiring more agent, and thus has a much higher climate impact on a system basis.

Consequently, the phase-out of production/consumption at the end of this year does not end the requirement to continue to manage banks of halons for decades

to come. For example, civil aircraft that are produced today have economic lifetimes of 30 or more years and will need to continue to be supported with halons, or face fire and life safety concerns or require expensive retrofit to high GWP alternatives. As Parties increasingly address mandatory decommissioning and subsequent destruction requirements, the long-term consequences of availability or non-availability of halons will become progressively more important. Parties with apparent current surpluses need to consider their and others long-term needs to avoid destruction for later production or reduction in fire and life safety protection. Long-term storage in physical banks or other banking mechanisms would help to ensure avoiding this pitfall. In determining needs for long-term storage and availability Parties may wish to consider the total climate impact of such measures and not just compare GWPs that while on the surface appear to be environmentally sound may in fact cause additional climate impact.

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## **7 Funding Sources and Factors Affecting Availability**

### **7.1 Sources of Funding (MLF, GEF, Carbon Markets, Other)**

As part of the response to Decision XX/7, the Ozone Secretariat was asked to assess potential sources of funding for ODS bank management. The resulting process included consultations with the United Nations Framework Convention on Climate Change (UNFCCC), the Global Environment Facility (GEF), the World Bank and the other UN-based Implementing Agencies under the Montreal Protocol.

Amongst the most significant findings from this consultative process were the following:

- The Multilateral Fund reported the approval of project preparation funds for six Pilot Projects on ODS Bank Destruction.
- The GEF may be considering merging its current Ozone focal area into a newly formed chemical management focal area bringing greater focus on lifecycle management issues. There may also be approximately US\$ 1.2 million available for short-term activities
- Although GEF's climate actions are focused on market transformation, particularly in the area of energy efficiency, there are opportunities to take advantage of synergies to manage lifecycle issues. This could include the management of ODS where equipment includes them.
- The World Bank indicated potential mobilisation in three areas. These were Donor Trust Funds, Special Project Development Funding and the mainstreaming of ODS management into the wider chemical management structures at national level. A number of these strategies could be operated independently of the Montreal Protocol itself.
- UNDP presented at the March/April Executive Committee Meeting its ideas for the establishment of an ODS Climate Facility which, through a donor-led fund and complementary oversight framework, has the potential to interact with the carbon markets. The ODS Climate Facility would effectively act as an interim mechanism, a step-removed from the voluntary markets, as a source of demand and to develop the credibility of credits.
- UNIDO is focusing on producer responsibility initiatives based on the levying of a small premium on new purchases to fund the end-of-life management of old equipment.
- In line with the findings of other consultees, the Ozone Secretariat confirmed that there was little likelihood of ozone depleting

substances being incorporated into the Kyoto basket or the umbrella of the CDM mechanism anytime soon. Some approaches for carbon markets (e.g. that of UNDP) foresee the eventual, long-term integration of ODS destruction into the compliance markets and therefore believe it important to develop and protect the reputation of such credits.

One of the over-riding aspects in all of the interactions with the climate community was that the approaching Copenhagen talks are dominating the climate agenda and it is difficult to get consideration of the issue at this time. However, initiatives at individual Party level (e.g. the federal proposals linking HFC strategies with ODS destruction under the Waxman-Markey Bill) could still play into the international arena and unexpectedly put ODS destruction into the spotlight.

## **7.2 Guidelines for Disposal Project Eligibility under the MLF**

As part of the Multilateral Fund's commitment to stimulating the ODS recovery and destruction activities, the Executive Committee of the Fund actioned the development of a set of Guidelines for defining project eligibility. These were presented and discussed at the 58<sup>th</sup> meeting of the Executive Committee in July 2009 and documented as UNEP/OzL.Pro/ExCom/58/19/rev1.

It is noted that the initial priority given by the Meeting of the Parties was to 'assembled stocks' implying that these are pre-existing. While this is certainly an obvious place to start, the Task Force believes that a broader range of project options needs to be included eventually. This therefore supports the position also taken by the Multilateral Fund Secretariat.

The definition of 'collection' extends considerably further than would be envisaged within this Report where much of the activity defined as 'collection' in ExCom 58/19 would be viewed as 'recovery' here.

Similarly, the definition of 'transport' used within ExCom 58/19 refers only to the movement of concentrated forms of ODS. It would not include the transport necessary to bring, for example, refrigerators to a centralised location for de-gassing and/or blowing agent removal.

The use of the terms 'storage' and 'destruction' are synonymous in both documents and do not create any further disconnection between the two approaches.

There is clearly a need to align the nomenclature used for such projects and the key difference appears to be in the absence of the 'recovery' step as a distinct activity in the process. The TEAP would be ready to further discuss this issue with the Multilateral Fund Secretariat at an appropriate juncture.

The focus on the evaluation of re-use (reclaim or recycling) is consistent with the discussions in this Report with Sections 8, 9 and 10. It could possibly be useful to make reference to the determination of the life cycle climate performance of the replacement equipment when decisions not to recycle are made.

The Task Force would fully endorse the call for a tracking system related to recovered (in terms of ExCom 58/19 'collected') ODS. This is something which is being actively pursued within the developing ODS Destruction Protocols and Methodologies as set out in Section 7.6.1.

As demonstrated in Section 6, the proposal to establish a threshold at US\$ 13.2/kg of ODS recovered will limit the activities to refrigerant management activities. This may be appropriate in the short-term bearing in mind their significance in overall potential recovery and destruction between 2010 and 2030. The broad geographic spread and, in particular, the inclusion of small island states seems very appropriate.

Although co-funding is cited as a desirable financial mechanism within the pilot projects, the precise nature of the funding packages is not yet known. As the discussions around the funding of such projects within the carbon market develops it is likely that on-stop-shop funding mechanisms may emerge even though there could be more than one funding stakeholder represented.

### **7.3 Early Experiences on Managing Banks under Existing Funding Mechanisms**

Early experience in seeking to manage ODS banks under existing funding mechanisms has led to considerable frustration. As noted in Section 7.1, the number of funding options available for the purpose is substantial, but very few, if any are tailor-made for the purpose.

Bearing in mind the potential significance of the investments involved, the Task Force believes strongly that considerable effort needs to be invested in designing a fit-for-purpose mechanism from the outset. Although there will always be an element of learning-by-doing, the creation of the appropriate funding vehicles at an early stage will avoid unnecessary and unfortunate precedents.

### **7.4 Aspects of Funding within the GEF (synergies with Energy Efficiency)**

The opportunity of combining equipment end-of-life management programmes with wider market transformation projects under the GEF and others is attractive. Indeed, this is one area where a degree of success has already been achieved in managing the decommissioning of chillers. Domestic refrigerators are among the other equipment types that could sensibly be included to add value to such programmes and to achieve ODS bank management at marginal cost.

In its assessment of ODS bank management costs in Section 6, the Task Force has not been able to make any quantifiable concessions to the economies that might be available through such programmes. However, the disadvantage will be that the timing, location and priority will be driven by other programmes.

As noted in Section 7.1, there is some hope that ODS bank management activities will become more mainstream for the GEF, but the latest information suggests that this might still be limited to the geographic regions covered by the Ozone Focal Area (Europe and CIS).

## **7.5 Extent to which Banks can be managed without Market Mechanisms**

The decision to proceed with pilot projects on the basis of a cost threshold of US\$ 13.2/kg of ODS destroyed gives some signal of intent. However, a brief comparison with the right hand column of Table 6-3 shows that this level of funding would only ever achieve the lowest hanging fruit.

Even at this level of funding, the potential funding requirement would reach in excess of US\$ 850 million per year by 2015 in developing countries for low effort refrigerants alone (see Figure 6-8). It is, of course, clear that not all of the refrigerant reaching the waste stream would be managed, but even a success rate of 20% would create significant additional burdens on the existing Multilateral Fund and double the basic triennial requirement.

Consideration is also being given currently to establishing a Facility for Additional Income, which would initially be a donor-led fund to augment the Multilateral Fund and stimulate climate beneficial actions. However, this is primarily focused on technology transfer impacts under Decision XIX/6 rather than ODS destruction projects.

Even then, the Facility for Additional Income is expected to reach out to the voluntary markets as the demand for project finance increases. Its ability to do so will depend on the preparations made to engage with these markets. This is the subject of Section 7.6.

## **7.6 Factors influencing the Availability and Efficacy of Carbon Finance**

The carbon markets can be delineated between compliance and voluntary markets. ODS destruction projects currently fall within the voluntary markets.

A number of concerns have been expressed about the potential engagement with the carbon markets, and particularly the voluntary sector. For example, one such general concern about carbon markets is that unscrupulous project developers will skim off the low hanging fruit and leave the more challenging ODS bank management activities to the Governments.



A key issue regarding the voluntary market is the size of the market and its capacity to absorb the future flow of credits from ODS destruction projects. In other words, there is a potential imbalance between the total demand and supply of credits in the voluntary market. By illustration, in 2008, the voluntary market was sized at 54 million tonnes CO<sub>2</sub>e in terms of volume of credits and US\$ 397m in terms of dollar value of credits. As set out earlier in Figure 3-10, the average annual Other Refrigerant 2010 climate benefit from ODS banks is estimated at 350 million tonnes CO<sub>2</sub>e. Section 7.6.2 specifically addresses this issue, generating several sensitivities on market size.

Related to market size and demand, there are those who are concerned that the nature of ODS destruction credits will not be very attractive to purchasers. The voluntary market, despite its chequered reputation, draws buyers who have no legal/compliance need to reduce emissions or offset their carbon footprints but often do so for social responsibility or public relations purposes. For many such buyers, the storyline behind the credit encourages the purchase. ODS destruction credits will be competing for demand with a variety of other credit types, including for example, renewable energy, forestry and project types with biodiversity or sustainable development stories. For those outside of the Montreal Protocol community, it might be difficult to see the incentive in contributing to the cause of ODS destruction, when many might argue that this should have been dealt with on a regulatory or compliance basis from the outset.

Another key issue is quality of credits, where the voluntary markets have been previously characterized by their lack of a centralized quality-control and accounting system (such as found in compliance markets like the CDM). There are concerns about voluntary market standards, and that the lack of reliable registries could result in multiple selling of the same credits.

In order to address these concerns, and develop a stronger case for market participation, there is a clear need to provide credibility to the credits. A number of stakeholders are working to this end. Section 7.6.1 highlights what has been done in the period since the Phase 1 Report and revisits the potential for the involvement of the Montreal Protocol institutions in assisting the future direction of these efforts.

### **7.6.1 *Registry and Methodology Issues (incl. Montreal Protocol engagement)***

#### **Protocols and Methodologies**

In the period between the completion of the Phase 1 Report and this Phase 2 Report there has been heightened activity in the development of Protocols and related Methodologies for the implementation of ODS bank management projects.

In general, Protocols are seen as frameworks in which project eligibilities, boundaries and guiding principles are defined, while Methodologies set out more

specific issues related to the choice of baseline, the calculation of greenhouse gas emission savings and the monitoring procedures required to comply with the Protocol. The third level of documentation is the Project Design Document (PDD) which focuses on a specific project description and geography. The PDD will typically explain how baselines have been chosen, how monitoring procedures will be applied for the specific project and how these choices comply with the Methodology with which they are linked.

This hierarchy of three closely-related pieces of documentation can lead to considerable overlap and there can be some blurring of the boundaries depending on the particular programme responsible for the documentation. What is key, however, is that the three levels of documentation are seen to intermesh coherently with one another to ensure that validation can be completed in a robust fashion in accordance with best practices – typically no less onerous (although hopefully less bureaucratic) than those applied for CDM Projects.

The Voluntary Carbon Standard (VCS) is one such programme that has launched a public consultation process on its draft ODS Protocol. This lists a number of eligibility criteria for projects which cover issues such as definitions of additionality, substance type and the timing of credits, where the draft Protocol endorses an approach to issue credits at the time of destruction.

A parallel Protocol development activity, including public stakeholder consultation, has been launched during the summer under the Climate Action Reserve (CAR). As with the VCS initiative, this centres round the crediting of ODS destruction and a number of the features are similar. However, the Protocols developed under CAR tend to be much more focused and prescriptive, making them closer to what would be considered a Methodology in other programmes. Although CAR has generally been a US-centric programme, it has sought to include in a separate, but related Protocol, the destruction of ODS recovered in Article 5 countries and then imported into the United States. . However, in the current drafts, the provision for the inclusion of projects where destruction is practised outside of the United States has not yet been included explicitly. This matter is under active consideration by CAR and could prove a significant factor in the adoption of the CAR Protocol by the Montreal Protocol community and, in particular, the Implementing Agencies.

There are additional linkages between the VCS and CAR Protocols, since it has become standard practice for VCS to accept all CAR Protocols as eligible Methodologies under their own programme. This may provide an opportunity for the justified rigours of the CAR Protocol to be carried forward into the international domain, if CAR should decide not to include destruction activities outside of the United States within its own eligibility criteria.

A further strand of development has been the emergence of ‘home-grown’ Methodologies from project proponents, equipment suppliers and others, usually

developed to advance their own projects. The complication for such an approach is that ultimately these orphan Methodologies need to find a home under one of the Protocols. However, since none of these is yet in place, no validator can validate the Methodologies themselves at this time. Despite much effort, therefore, the initiation of widespread carbon-financed ODS projects has still not seriously taken place. One project launched under a Blue Source Methodology has been implemented for the destruction of CFCs in medical aerosols on the understanding that this will ultimately be captured under the umbrella of the American Carbon Registry.

As documented in both the Phase 1 Report, the Chicago Climate Exchange has sought to take a lead in the field because of its shorter time-scales for approval. However, its lack of public stakeholder process or use of an external expert peer review has made widespread acceptance of its own Protocol unlikely. This has been recently underscored by the text of the Waxman-Markey bill which requires these review processes to be practiced for offset eligibility under the proposed legislation.

With these developments in mind, it appears that the CAR Protocols will be the first to be formally introduced, assuming that the Board approves both the Domestic and International Documents at its next meeting in February 2010.

### Registries

A number of these programmes in the Voluntary Carbon Market (VCM) have their own registries. The Climate Action Reserve maintains its registry, measured in Climate Reserve Tonnes (CRTs), and would plan to extend this registry to cover ODS destruction projects. Because of the reputation of CAR for rigorous Methodologies, the value of CRTs tends to be somewhat higher than for more typical VERs. Values in the range of US\$ 5-12 might be expected at the current time, whereas, for VERs, the current values might peak at around US\$ 5-6 per tonne.

Other programmes, including VCS, are already in the process of introducing registries. However, it is now recognised in the VCM that this is a major undertaking. It is likely that VCS will succeed, but that success, coupled with the existing status of CAR, will act as a catalyst for a two-tier system within the VCM. In the short-term at least, it is likely that the two organisations holding developed ODS Protocols will also be the only two holding active registries.

### The Potential Role of the Montreal Protocol Bodies

In the Phase 1 Report, the prospect of the Montreal Protocol bodies developing their own registry was discussed. However, a greater knowledge of the complexities involved in achieving this development has left the Task Force believing that the Montreal Protocol might be better served by seeking a

mandatory reporting requirement from those programmes hosting ODS destruction projects. Parties may consider that this reporting requirement either be delivered via the country in which the programme is based, or directly with the programme itself. As one option, this reporting process could be collated by the Ozone Secretariat alongside its other responsibilities for report coordination.

Using this approach, it might be possible to say that only those programmes which report to the Ozone Secretariat would be recognised by the Protocol. This could potentially have an impact on the credibility of those programmes and the credit price that could be achieved. Assuming that this would lead to gravitation of most, if not all, projects towards these programmes, the Ozone Secretariat might be able to track the level of destruction occurring through mechanisms such as the VCM on a year-by-year basis.

If the Parties wish to do so, they could recognise, (rather than endorse) those programmes with robust registries. They might also wish to ensure that the Protocols and Methodologies supported by the programmes are equally rigorous through initial assessment by one of the existing Montreal Protocol bodies and periodic review thereafter. To be completely fair and transparent, this offer would also need to be made available to any new entrant that might subsequently emerge.

Recognising that the current CRT price range of US\$ 5-12 per tonne CO<sub>2</sub>-eq. would only just be sufficient for ODS destruction project purposes, it is open for the Parties to discuss how the Montreal Protocol and its possible engagement could enhance the perceived value of ODS destruction credits. If it were to be successful, then the 'Other Refrigerant' projects could become relatively worthwhile.

The question for the Montreal Protocol Parties to resolve on behalf of their institutions would be whether it would want to see these profits go to project proponents or to secure them for cross investment into projects within the 'Appliances & Foams' sector. This is clearly a policy decision that would have substantial consequences for the structural design of the funding mechanism.

### **7.6.2 *Impact of Unfettered Flow of ODS Credits on Carbon Price***

The capability of the voluntary carbon market to absorb the activities related to ODS destruction has been a subject of study in parallel for both the Task Force itself and also the World Bank via its consultant ICF Inc. The ICF Report reaches the conclusion that the voluntary market should be able to cope with the credits emerging from the ODS destruction activities, but bases this conclusion on the likelihood that the uptake of projects will peak at around 10% of the overall annual potential.

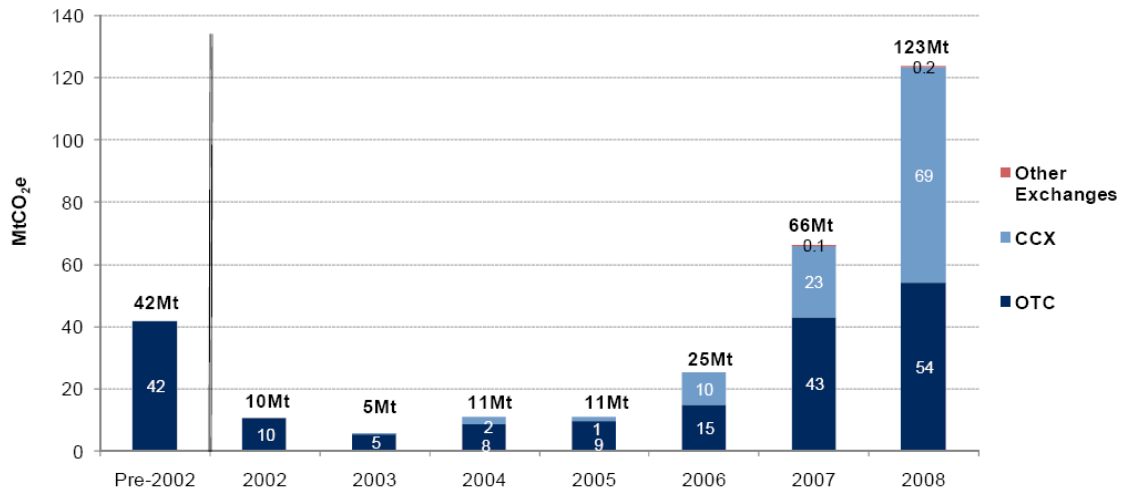
Clearly, it is very difficult to forecast with any degree of certainty the size of the future voluntary market, and the uptake of ODS destruction projects will depend on both the capacity to cope with projects and the likely demand for credits. As noted in the introduction to Section 7.6, there could be some significant buyer sensitivities in the voluntary market that might not be replicated in the wider carbon markets (compliance or pre-compliance). With potential uncertainties on both the supply and demand side, the Task Force is less optimistic that the voluntary carbon market will be able to handle this opportunity in isolation. It is clear, however, that it will definitely assist in the establishment of the structures to achieve an operative market.

One of the challenges for ODS recovery and destruction projects is that the demand is potentially immediate and early failures, or sub-optimal solutions, will result in the irrevocable loss of significant opportunities. This is a large risk to take with one mechanism. To this end, the Task Force believes that consideration also needs to be given to wider carbon market approaches which might serve to spread the risk more broadly. This, in essence, is the approach foreseen within the ODS Climate Facility and, to a lesser degree, the Facility for Additional Income, where donor funding is seen to provide a buffer between the projects and the markets. A more detailed analysis of the arguments is set out in the following paragraphs.

The Task Force certainly does not disagree with the analysis of the voluntary market as provided by the ICF Report. In fact both Reports draw upon the same source material. The voluntary carbon market has grown steadily since its inception in the late 1990s. However, that growth has been dramatic over the last three years, as shown in Figure 7-1. One of the reasons for this has been the growth in transactions taking place on exchanges such as the Chicago Climate Exchange. This has largely been in anticipation of future compliance requirements within the United States of America (the so-called pre-compliance market activity). This part of the market tends to de-link buyers from the projects in which they invest and the ethical 'feel good' component of the more typical over-the-counter transaction is lost.

Many are suggesting that the growth seen between 2007 and 2008, which has largely been in the CCX-based environment, could be transient and that the market might recede just as rapidly once the future compliance strategy of the United States is clear. Account also needs to be taken of the fact that market data of this type takes account of all 'trades' not just the initial one relating to the original emission reduction. A more meaningful figure is therefore derived from aggregating carbon emissions being reduced by projects covered under the market.

**Figure 7-1: Growth of the Global Voluntary Carbon Market**



Source: Ecosystem Marketplace, *New Carbon Finance*.

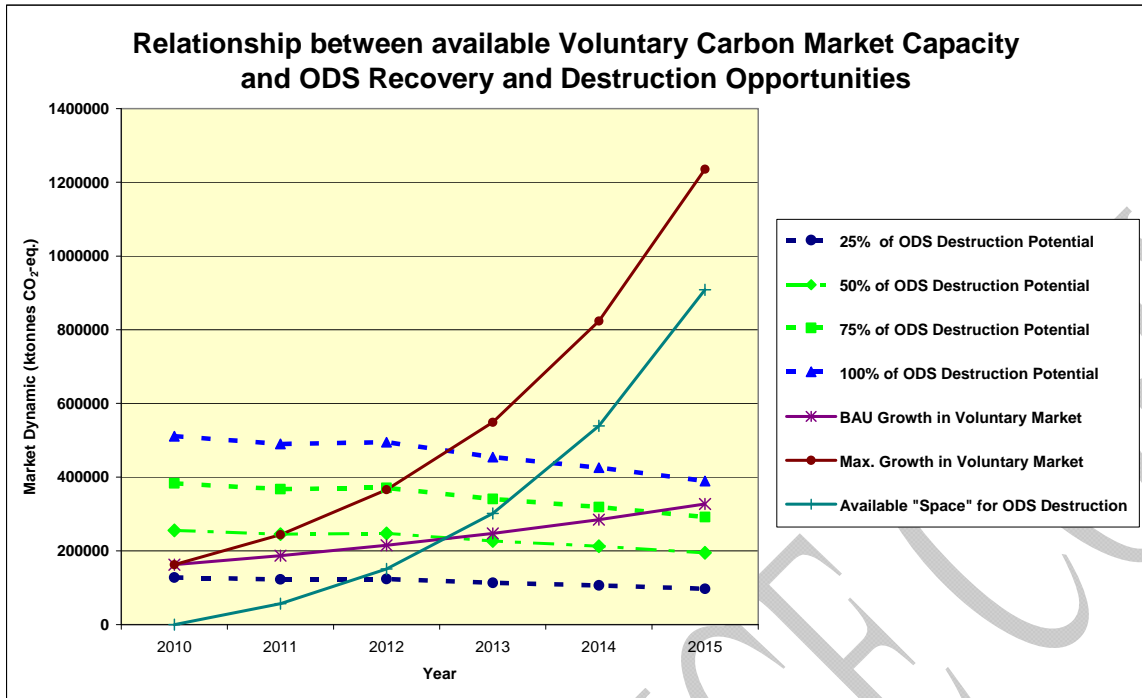
With these aspects in mind, although the market doubled in size over the last year, the same information source (Ecosystem Marketplace) is predicting a growth rate of no more than 15% per year over the next decade in a business-as-usual scenario. Some are even questioning whether there will be any growth at all.

Bearing in mind the relative size of the ODS destruction opportunity, the question to be asked is how much more growth could the market accommodate, on a year by year basis, and still maintain stability. Some might argue that, if the market has doubled within the last year it could continue to double year-on-year. However, most will know that business models are seldom able to replicate such levels of growth on a sustained level and periods of consolidation are required.

The Task Force has taken the rather ambitious assumption that the voluntary carbon market might be able to sustain up to a 50% year-on-year compound growth rate over the next ten years. Discounting for the 15% year-on-year growth envisaged in the business-as-usual case, the differential between one growth rate and the other can be derived and then compared against the potential demand arising from the ODS recovery and destruction project markets.

Figure 7-2 below illustrates how the capacity to deal with ODS Recovery & Destruction projects could grow with time, based on an overall voluntary carbon market compound annual growth rate of 50%. In this instance, it can be seen that there will be sufficient capacity to deal with 100% of the emerging waste stream by 2014. However, even then, ODS recovery and destruction opportunities up to a 1.44 billion tonnes CO<sub>2</sub>-eq. may have been ‘missed’. These ‘missed’ opportunities will be even greater if the growth of the voluntary market is constrained by any other factors. Table 7-1 below illustrates this risk.

**Figure 7-2: Relationship between the Voluntary Carbon Market capacity and potential ODS Recovery and Destruction Opportunities (based on 50% annual compound growth)**



Therefore, it can be seen that the responsiveness of the voluntary carbon market to growing project volumes is a critical factor in the overall accommodation of the ODS recovery and destruction opportunity.

**Table 7-1: Impact of Limitations on Voluntary Market Growth Rates**

Annual VCM % Growth	Peak % share of ODS Credits	% of ODS Annual Arisings Manageable					Bank Missed (Gt CO <sub>2</sub> -eq.)
		2012	2014	2016	2018	2020	
20%	32%	4%	12%	29%	61%	100%	3.23
25%	44%	8%	26%	65%	100%	100%	2.50
30%	48%	12%	42%	100%	100%	100%	2.11
40%	54%	21%	80%	100%	100%	100%	1.69
50%	55%	31%	100%	100%	100%	100%	1.44

However, even more critical to the overall case for reliance on the voluntary market is the risk that there is little or no demand for the credits so produced. Table 7-1 provides additional information on the likely share of the total voluntary carbon market that ODS credits could represent at their peak. For the overall market growth rates considered, this peak can represent 32-55% of the total market. Clearly, even introducing those credits onto the market at that level would have a significant pricing impact and, the impact on the ODS component of

the credits could be even greater if they are perceived as less attractive than other voluntary credits available at that time. The net effect would be that the market would self-correct because the money to fund the on-going recovery and destruction would not be there. However, the consequences for the climate would be substantial if the total project portfolio were to collapse.

Ecosystem Marketplace provides a further insight into the potential of the carbon markets by providing an overview of the total carbon market activity. This is presented in Table 7-2 below:

**Table 7-2 Total Size and Value of Global Carbon Markets (2007-2008)**

**Transaction Volumes and Values, Global Carbon Market, 2007 and 2008**

Markets	Volume (MtCO <sub>2</sub> e)		Value (US\$ million)	
	2007	2008	2007	2008
Voluntary OTC	43.1	54.0	262.9	396.7
CCX	22.9	69.2	72.4	306.7
Other exchanges	0	0.2	0	1.3
<b>Total Voluntary Markets</b>	<b>66.0</b>	<b>123.4</b>	<b>335.3</b>	<b>704.8</b>
EU ETS	2,061.0	2,982.0	50,097.0	94,971.7
Primary CDM	551.0	400.3	7,426.0	6,118.2
Secondary CDM	240.0	622.4	5,451.0	15,584.5
Joint Implementation	41.0	20.0	499.0	294.0
Kyoto [AAU]	0.0	16.0	0.0	177.1
New South Wales	25.0	30.6	224.0	151.9
RGGI	-	71.5	-	253.5
Alberta's SGER <sup>(a)</sup>	1.5	3.3	13.7	31.3
<b>Total Regulated Markets</b>	<b>2,919.5</b>	<b>4,146.1</b>	<b>63,710.7</b>	<b>117,582.2</b>
<b>Total Global Markets</b>	<b>2,985.5</b>	<b>4,269.5</b>	<b>64,046.0</b>	<b>118,287.0</b>

Source: Ecosystem Marketplace, *New Carbon Finance*.

This table needs to be handled with care, since it contains transactional information on allowances (e.g. EU ETS) and secondary trades (Secondary CDM). However, the underlying project-based carbon activity is in excess of 400 Mtonnes CO<sub>2</sub>-eq and is at least eight times larger than the underlying voluntary market.

Although the percentage of the compliance market taken up by ODS destruction credits could still be highly significant on current evidence, it needs to be recognised that the compliance market can, and almost certainly, will grow substantially itself over the next five years. Bearing in mind that ODS are currently excluded from most, if not all, of the regulated markets and that it will take some time to alter this reality, and also accepting that the low and medium effort banks will never be recovered in their totality, the real impact of ODS



inclusion might probably be no more than 20% in practice. However, while the capability to absorb the credits could exist in future, and the purchasing community for compliance credits might be less fickle, there is no current way of joining these two components together.

### **7.6.3 *Bridging the Gap to the wider Carbon Markets***

The concepts presented to the Ozone Secretariat in a number of different guises during its research for its Decision XX/7 Report in July and covered in Section 7.1 of the Report, are largely means of potentially leveraging climate funds either via markets, via donor-led trusts or via combinations of the two.

The challenge of proceeding along the donor-led route is the sheer scale of the task. The time series presented in this report shows that, close to US\$ 3-5 billion/year would be required, in totality, to manage the low and medium effort refrigerants in developing countries. Obviously, lower proportions of funding would achieve pro-rata lower proportions of recovery and destruction – possibly even lower than the voluntary carbon market in the worst instance. The history of the Montreal Protocol would not normally support expectations of such high levels of donor funding. However, in the context of climate policy options being considered by many Governments, such significant and relatively cost-effective savings could be helpful in supporting more aggressive cap and trade measures domestically. Essentially, national or regional climate schemes could become bridges to the wider climate markets in due course.

The ODS Climate Facility has been presented as one way of providing such a link. It would effectively act as a short to medium-term guarantor of demand for ODS credits arising from projects – possibly even on a cost-plus basis. However, in such a proposal, there is a recognition that the markets would need to be given time to prepare for, and adjust to, the eventual in-flux of these credit streams and that some form of buffer fund would be necessary in the interim. If, for example, 3-5 years notice was needed to prepare, the capital required to hold these credits could be anything between US\$ 10 billion and US\$ 25 billion. In the context of the overall cumulative costs of bank management presented in the Phase 1 Report, these values are probably not excessive (5-15%), but remain substantial funds to construct and maintain.



## 8 Decision-Making with Respect to Destruction

Annual leakage rates for refrigeration sectors were shown as follows in the TEAP Report in response to Decision XVIII-12 back in 2007.

*Table 8-1: Default Annual Bank Emissions Factors for ODS in Common Use*

Sector	Sub-sector	DEVELOPED COUNTRIES							DEVELOPING COUNTRIES						
		CFCs		HCFCs					CFCs		HCFCs				
Emission Factor	(%) @ 2015	11	12	22	141b	142b	123	124	11	12	22	141b	142b	123	124
Refrigeration	Domestic	-	8.4	-	-	-	-	-	-	13.8	-	-	-	-	-
	Commercial	-	58.7	33.6	-	-	-	34.4	-	70.3	39.5	-	-	-	33.3
	Transport	-	-	40.0	-	-	-	-	-	88.6	44.3	-	-	-	-
	Industrial	15.8	15.7	15.7	-	-	-	-	17.1	20.4	16.7	-	-	-	-
A/C	Stationary	24.8	24.6	14.8	-	-	9.4	-	25.6	23.4	12.7	-	-	18.8	-
	Mobile	-	36.0	48.6	-	-	-	-	-	35.4	45.6	-	-	-	-
<b>Average</b>	Refrig. A/C	24.3	20.0	20.8	-	-	9.4	34.4	25.4	24.3	28.5	-	-	18.8	33.3
Foams		1.1	0.8	1.0	1.6	0.8			2.2	3.8	0.4	1.6	1.8	-	-
Aerosols	Medical	-	-	-	-	-	-	-	100	100	-	-	-	-	-
	Non-medical	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solvents		-	-	-	50.0	-	-	-	-	-	-	50.0	-	-	-

According to the Decision XX/8 Report, the banks in the relevant refrigeration sub-sectors can be summarised as shown in Tables 8-2 and 8-3 below:

*Table 8-2: Estimated Bank Sizes of Refrigerants in 2020 (Developed Countries)*

2020	CFC	HCFC	HFC	OTHERS	Total
DOM	320	-	80,784	17,050	98,154
COM	-	22,456	302,623	-	325,079
TRA	-	3	20,004	-	20,006
IND	8,542	32,252	90,566	89,219	220,579
SAC	2	210,170	824,337	1,548	1,036,056
MAC	5	2,359	493,973	10,706	507,044
Total	8,869	267,240	1,812,287	118,523	2,206,918

*Table 8-3: Estimated Bank Sizes of Refrigerants in 2020 (Developing Countries)*

2020	CFC	HCFC	HFC	OTHERS	Total
DOM	11,963	-	163,444	6,901	182,308
COM	-	699,596	245,366	-	944,962
TRA	-	3,699	2,815	-	6,514
IND	9,475	87,328	28,673	49,262	174,738
SAC	1,466	456,230	266,006	384	724,087
MAC	-	7,040	197,748	-	204,788
Total	22,904	1,253,894	904,052	56,547	2,237,397

Based on a business-as-usual scenario for default emissions for developed and developing countries as outlined in Tables 8-1, combined with the bank size information in Tables 8-2 and 8-3, the ‘apparent demand’ can be derived as shown below in Table 8-4.

**Table 8-4: Estimated Servicing Demand for ODS by Region and Type in 2020**

<i>Refrigerant</i>	<i>Developed Countries</i>	<i>Developing Countries</i>
	<i>(tonnes)</i>	<i>(tonnes)</i>
<b><i>CFCs</i></b>	<b><i>1,950</i></b>	<b><i>5,725</i></b>
<b><i>HCFCs</i></b>	<b><i>56,120</i></b>	<b><i>351,090</i></b>

It is, therefore, self-evident that overall global servicing demand will exceed that entering the waste stream in 2020 and probably throughout the period. This raises a clear question about whether ODS refrigerants at end-of-life should be destroyed at all!

One complication in making this judgement is that there are no formal statistics on the amounts of ODS currently being recycled globally or regionally, since this is not an issue that requires monitoring under the formal reporting requirements of the Montreal Protocol. Anecdotal information from experts in the field suggests that the recycled component of servicing demand varies between 0% and 20% depending on the sector. A further analysis would be required to obtain a more informed opinion on this, but such an estimate would suggest that somewhere between 25,000 and 75,000 tonnes of ODS might be being recycled annually as of today.

This future trends related to this estimate are dependent on strategies in various regions. In the European Union for example the placement on the market for reclaimed and recycled HCFCs will only be allowed until 2015 under the recast EC Regulation, while in the United States of America, demand for recycled HCFC-22 is expected to increase markedly as allowable new production levels drop. These factors are likely to drive demand, and ultimately the price achievable for recycled materials.

Bearing in mind that there is almost certainly sufficient servicing demand, even now, to avoid the destruction or release of ODS, the question needs to be raised as to why so much material is vented with neither destruction nor recycling. The key to the answer almost certainly lies in the lack of awareness and infra-structure to support the recovery and the relative continued abundance of newly manufactured product. In practice, the issue comes down to price competition between recycled material and newly manufactured product. This matter is explored further under Section 9.

## **8.1 Factors favouring decisions to Re-use or Recycle**

Even if there is a recognisable demand in the locality for reclaimed or recycled material, a number of requirements need to be met in order for it to be used. The following sub-sections briefly review these arguments.

### **8.1.1 Purity of Available Substance**

As noted in the Phase 1 Report, dealing with recovered refrigerant at the end-of-life stage often means that supplies are contaminated with oils or other impurities. Where the recovered refrigerant can be recycled into the same, or equivalent, equipment, the need for a costly reclamation step can be avoided. Therefore, recycling can be maximised where there is a significant population of similar equipment.

If there is a particularly pure source of a refrigerant, even under end-of-life conditions, this will only make the ability to recycle easier.

Where reclamation is the only option it is important that the price for reclaimed refrigerant is maintained at a sufficiently high level to encourage the practice and minimise venting.

### **8.1.2 Equipment Age and Condition**

Recycling is most appropriate into equipment with relatively low leak rates – either because it is comparatively new or because it has been recently refurbished. This should always be a factor in considering decisions to recycle. It would be particularly inappropriate to prolong the life of equipment which demonstrates poor energy efficiency, since a further climate impact would be created by doing so.

### **8.1.3 Existing Equipment relying on Specific Substance without Low Cost Retrofit Option**

The availability and cost of retrofit measures or replacement equipment is always a factor in deciding whether to continue reliance on virgin or recycled materials. As with the situations covered under Section 8.1.2, this needs to be an objective decision based on the balance of issues. However, in most cases, the decision is likely to be coloured by capital and revenue budgets, particularly in the difficult current financial circumstances.

### **8.1.4 Lack of Immediate Replacement Technologies**

There will be some instances, where there is no choice in the matter because of the lack of a technically feasible alternative. However, as noted in TEAP's Report in response to Decision XX/8, this is likely to be a rare event. A more common one, will be the potential that a replacement technology has similar or worse life cycle climate performance. In such instances, it would certainly be justified to

continue with the use of an existing technology, particularly if it were known that a more climate-favourable option was under development.

## **8.2 Factors favouring decision to Destroy**

From another perspective, there may be arguments that making recycled material available only elongates the lifetime of existing equipment and prolongs the period over which HCFCs will be released (from whichever source they come). The following sub-sections cover the factors that might influence a decision in favour of destruction.

### **8.2.1 *Mixture of ODSs or Significantly Contaminated Substance***

Where only significantly contaminated sources of refrigerant are available, there may be no real alternative than reclamation. As noted in Section 8.1.1, reclamation can only be practiced where the costs can be covered by the value of the resold refrigerant. Accordingly, in regions where there is little demand or where there is plentiful supply of virgin material, it might be better to destroy the material. This will certainly be better than the venting option.

Although costs of destruction are likely to be relatively modest, and could, under certain circumstances, be offset by carbon finance, the availability of virgin material in the region could prevent this offset in practice for reasons explored in more detail within Sections 9 & 10.

### **8.2.2 *Desire to Accelerate Technology Transition***

In other circumstances, the regulators may have decided that the only way to reduce reliance on ODS refrigerants is, in the first instance, to ban the manufacture of new equipment based on an ODS refrigerant and subsequently to progressively limit the amount of that refrigerant that can be recycled. This is often achieved by introducing use bans across sub-sectors of the wider refrigeration and air conditioning sector. Under these circumstances, the market for recycled materials could be severely curtailed.

As noted in Section 8.1.2, there would be a clear need to avoid casual venting and this is often done by the introduction of a venting ban or mandatory destruction.

### **8.2.3 *Linkage with wider Waste Programme at Product/Equipment Level***

Particularly in the case of domestic refrigerators, there can be programmes which are focused primarily on the early retirement of the equipment itself. These programmes are often driven by energy efficiency considerations. It would therefore be completely inappropriate to seek to extend the life of such equipment by any form of recycling. In some instances however, for example in the recovery of CFC-11 from foams in domestic refrigerators, there are markets completely unconnected with the previous use (in this case, chillers) and recycling can therefore be a viable alternative.

#### **8.2.4 Control of Illegal Trade**

The retention of existing equipment and the on-going recycling of ODS refrigerants to service it can extend markets into which illegally traded production from other countries can blend more easily. The lack of any formalised reporting on recycled quantities means that identification of illegally traded materials needs to rely on 'intelligence' rather than on any form of mass balance.

In summarising this Section of the Report, the Task Force would have liked to have been in a position to present some form of hierarchy based around the three key options of venting, recycling or destroying. While it is obvious to all that venting is at the bottom of the hierarchy, and arguably never justified, the decision about whether recycling is a better option than destruction is clearly one that depends on a number of local and regional issues that cannot be generalised. However, the question that the Task Force can address is whether the introduction of incentives for destruction distort the decision. This is the subject of the next Section.





## 9 The Influence of Carbon Price on Decisions to Destroy or Recycle

A concern that is rightly voiced about decisions to destroy material is whether there would be additional benefit from re-use or recycling. As concluded in Section 8, this is a very particular decision and can only be seriously reached at a local level, given the regulatory framework and other circumstances pertaining.

When looking at the influence of incentives to destroy, there are three prices to consider:

1. The price of virgin material
2. The price for which recovered material could be sold after reclamation/recycling
3. The price that would be offered by a proponent of a destruction project

A number of scenarios can be envisaged:

- Where the virgin material has the lowest price, it will be used and there will be no market for recycled material. In this instance, the decision would be between venting and destruction. Assuming the financial considerations are the only driver, the decision to destroy will only be made if the destruction creates a financial benefit (i.e. the incentive outweighs the cost)
- Where the recycled material has a lower cost than virgin material, or where virgin material is not available, there will be a market for recycled material with prices driven by supply and demand. A decision to preferentially destroy will only be made if the profit from destruction would be greater than profit from the sale of recycled material after the costs of recycling or reclamation have been deducted. It is clear that, in the absence of any destruction option, the recycled material would not be placed on the market at a loss, so, in practice, the destruction must be more profitable than recycling to justify it preferentially.
- In a circumstance where there is no market for an ODS, then destruction is the only option and no market distortion is experienced.

The approach that the voluntary carbon market is taking to the subject is important in this context. The Climate Action Reserve (CAR), in particular, is giving careful thought to the avoidance of perverse incentives. It is doing this in a number of ways, one of which is the definition of a carbon project's baseline.

### 9.1 Defining the Baseline for Refrigerant Destruction Situations

Under the three scenarios provided in the previous section, the baselines would be defined as follows:

- Where virgin material is currently available, there would be no possibility of a carbon project being conducted because the scope of the Protocol would preclude the recovery and destruction of any ODS which is still being manufactured or supplied in the territory.
- Where recycled material was the preferred (or only) choice for the residual market, the project baseline would be defined in terms of the expected emission profile of that recycled material. Depending on average leak rates, the credit flow could be relatively modest or, in the case of leaky equipment, relatively generous. In this case, the Protocol would be discouraging recycling in leaky equipment (a good thing) but encouraging recycling in areas where leak rates are low by providing less credits (value) for destruction.
- Where there is no market for recycled material, the only alternative is venting and this would become the baseline. The project would then receive the maximum value for its emission abatement through destruction.

It can be seen that such an approach deals quite sensitively and objectively with the decision between destruction and recycling

## **9.2 Current thinking on pricing**

It has already been established that the recycling option would need to be profitable to be practised. Therefore, the first pre-requisite for destruction to compete as an option at all would be for destruction to also be profitable.

Although this assessment of profitability will depend on a number of regional and temporal aspects, the current situation with bulk refrigerants, as derived from this Report, leads to the conclusion that average costs are currently in the region of US\$ 5 to US\$15 per tonne CO<sub>2</sub> saved based on current waste stream mixes (see Figures 6-11 and 6-12). An important point to note here is that ODS Destruction Protocols and Methodologies will only credit the ODS components of any recovered mix. HFCs would need to be handled under the Kyoto mechanisms (e.g. CDM) where these apply.

A current valuation of a CAR credit ranges from US\$ 5-12 per tonne of CO<sub>2</sub> saved, therefore making the arrangement at present day values just about one of cost coverage more than profit, but only then if the baseline is based on venting as the baseline, which it will not be when recycling is an option.

## 10 Further Reflections on Avoidance of ‘Production for Destruction’

The emerging Protocols and Methodologies are, in general, taking a firm and conservative line on the potential risk of production for destruction. For instance, the Climate Action Reserve is in the process of deciding that it will not count as eligible any ODS substance for which production has not been phased out. Where ODS are imported for destruction, the National Ozone Unit in the country of origin will be required to write a letter to the Climate Action Reserve confirming that production of the ODS being imported has ceased and stating the date on which it did so.

This is a laudable, and rightly conservative, approach to the subject of avoiding production for consumption. However, it does run the risk of excluding a number of bona fide sources of ODS materials being destroyed. Therefore, consideration is also being given to ODS substances from sectors in which a use-ban already exists. This could, for example, include HCFC-141b in foams within the territorial boundaries of the United States, but would not be appropriate (or probably economic) for foams shipped from countries in which manufacture of HCFC-141b containing foams is still allowed.

When eligibility of a project is driven by ‘sector of use’ as well as ODS substance considerations, it is extremely important to have an adequate record of chain of custody. This is something that may be easier to achieve in some sectors (e.g. foams) than in others (e.g. bulk refrigerants). However, the Task Force considers that it is important for efforts to be placed into strengthening chain of custody provisions where appropriate in order to maximise recovery levels, rather than to default to a substance-only based regime which is conservative, but unambitious.



## 11 Final Conclusions

This Report has taken the initial information presented in the Phase 1 Report and has elaborated it further in a number of ways. In reviewing the conclusions of the Phase 1 Report against the findings of this Report, nothing concluded at that time has been countermanded. Moreover, certain conclusions have now be refined in the light of the further analysis contained in this Report. The following additional conclusions are therefore drawn:

- The collection, recovery and destruction of refrigerants of all types represent the most immediate and cost-effective method of mitigating climate impacts from the release of ODS Banks.
- Developing countries offer particularly valuable opportunities over the next 10-15 years during which the CFC proportion remains significant in the refrigerant waste streams. The on-going prevalence of HCFC-22 in these waste streams will also maintain a significant climate return over the period up to 2030.
- For developed countries, the opportunity for end-of-life management of ODS-containing refrigerants will broadly be over by 2025. However, the management of the ODS Substitutes at end-of-life, many of which contain HFCs, will provide an on-going climate benefit from any infra-structures created to manage ODSs.
- The global flow of ODSs into the waste stream is expected to peak at 200,000-225,000 tonnes annually within the period 2018-2020 with over 90% of this amount being refrigerant. Although estimates of ODS destruction capacity are still preliminary, it is not anticipated that additional global capacity will be required, even if the level of activity in ODS bank management increases substantially. Nevertheless, there will be significant logistic challenges in delivering recovered ODS to appropriate destruction facilities.
- Decisions to include ODS Substitutes within the scope of end-of-life activities could increase the demand for destruction capacity to as much as 400,000-450,000 tonnes annually by 2030, although some segregation and de-selection might be expected for those ODS Substitutes seen as relatively benign.
- Most refrigerant management plans implemented under the Montreal Protocol are focused on recovery to reclaim and recycle. As demand for servicing needs reduces in the period after 2015, active consideration needs to be given to the destruction of materials arising in this cycle. However, premature destruction which might stimulate re-manufacture must be avoided.
- Several protocols and methodologies are emerging within the voluntary carbon market community, the most notable of which are driven by the Voluntary

Carbon Standard (VCS) and the Climate Action Reserve (CAR). Both take a conservative view on the substances which should be included to avoid perverse incentives and take due care of accounting for ODS replacements.

- Early retirement of refrigeration equipment could be justified on the basis of improvements in energy efficiency. However, early retirement in order to manage the ODS banks could be counter-productive if the replacement technologies offer no additional benefit in life cycle climate performance.
- The holistic management of domestic appliances has been practiced in both Europe and Japan for several years. The overall cost of the process in climate terms remains below US\$ 50 per tonne of CO<sub>2</sub> saved while significant quantities of CFCs persist in the waste stream but the situation will deteriorate thereafter.
- In developing countries, the CFC component in the domestic refrigerator stream will continue until at least 2020 but investment costs for the fully automated recovery and destruction of all ODS may not be supportable in all cases. Newer semi-automated refrigerator recycling plants may reduce the investment burden to some degree, but it is expected that many developing country regions will be obliged to focus exclusively on refrigerant extraction (Stage 1) processes.
- The potential for the funding of ODS Bank management activities continues to receive significant attention and a number of ideas are continuing to mature. There remains concern that unfettered use of the voluntary carbon markets could strip out the low hanging fruit from the ODS banks and leave the more challenging areas unaddressed.
- The overall scale of the funding task also remains a significant and imminent challenge, particularly since ODS waste streams in the low and medium effort categories are currently at their peak. Linkage to wider climate programmes seems an inevitable step if the funding requirements are going to be substantively met.
- Insulating foams will be a minor source of ODS in the waste stream in the period to 2030. Current costs of recovery and destruction suggest that such projects will not be justified based solely on climate investment criteria. The combining of ODS flows (e.g. as with refrigerants and blowing agents in domestic refrigerators) may be an appropriate means of optimising foam bank management.
- Halons are unlikely to be included in near-term ODS destruction strategies and indeed the draft Climate Action Reserve standard excludes them from scope. This places further emphasis on the need to manage long-term stocks carefully to avoid unnecessary releases.

## 12 Annex

### Summary of suggested work for the TEAP to cover in the finalization of its report

TEAP was requested to complete the second phase of the reporting process requested by Decision XX/7 in time for the Meeting of Parties and to take into account the following guidance to the extent possible:

- Paying close attention to the guidance provided by Decision XX/7, in particular the paragraph 7 chapeau which inter alia calls for the relative costs and environmental benefits to the ozone layer and the climate, of destruction versus recycling, reclaiming and reusing such substances.
- In relation to environmental benefits, the TEAP is asked to consider ozone benefits, climate benefits, and any other follow-on economic, social and environmental benefits that might accrue such as benefits to waste management streams and to management of environmental harmful substances.
- The need for a detailed breakdown of costs associated with the destruction of ODS banks, including by category of process (such as collection, transportation, storage and destruction), as well as the relative costs and environmental benefits of destroying ODS banks by some subregions and by time period (taking into account when ODS banks can be best addressed). The TEAP is asked specifically to include, if possible, the costs of transportation of ODS to destruction facilities for those countries without destruction facilities, the costs and risks of possible long term storage of ODS, and to further delineate the costs in the domestic refrigeration sector relating to the capture and destruction of blowing agent and refrigerant components.
- The practicalities related to separation of various ODS, especially those for which production and consumption has already been phased-out, and provide more detail on the benefits and negative impacts of dealing with a mix of substances and sectors based on their availability and on other possible perverse consequences resulting from destruction, such as early retirement of equipment.
- Further information on the possible effect of the generation of carbon credits from ODS destruction on the existing voluntary carbon market including the timing of such credits being generated, the importance of credibility of such credits and how to enhance the credibility of such credits, and how to ensure that perverse outcomes do not arise (such as in relation to the compliance market) with input from the World Bank study being undertaken through the Multilateral Fund.

- Any information that might be taken into account from the approval of interim disposal guidelines by the ExCom at its 58<sup>th</sup> meeting, and from any project proposals received before finalisation of the report.
- Inclusion of factors that might influence the development of regional and sub-regional destruction centres.

#### Summary of suggested further work for the Ozone Secretariat

The Ozone Secretariat was requested to continue the analysis commenced in document UNEP/OzL.pro/Workshop.3/2, and in that regard:

- To categorize the funding opportunities included in its report as follows: funding opportunities falling under the purview of the Montreal Protocol itself, funding opportunities that involve cooperation between the Montreal Protocol and other institutions including co-financing, funding opportunities that can be taken by individual Parties, and funding opportunities that can be taken independently by other institutions
- To continue its consultations with the World Bank, Global Environmental Facility, and the various Multilateral environmental agreement Secretariats and to report on any further progress of relevance
- To provide further information on producer or manufacturer responsibility/take back programs
- To compile of information related to past discussions that have taken place on legal issues associated with the Multilateral Fund financing destruction of ozone depleting substances