MONTREAL PROTOCOL

ON SUBSTANCES THAT DEPLETE

THE OZONE LAYER

UNEP

Technology and Economic Assessment Panel

TASK FORCE DECISION XX/7 – INTERIM REPORT

"ENVIRONMENTALLY SOUND MANAGEMENT OF BANKS OF OZONE-DEPLETING SUBSTANCES"

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The text of this report is composed in Times New Roman.

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DISCLAIMER

ACKNOWLEDGEMENTS

The UNEP Technology and Economic Assessment Panel and the XX/7 Task Force co-chairs and members wish to express thanks to all who contributed from governments, both Article 5 and non-Article 5, to the Ozone Secretariat, as well as to a large number of individuals involved in Protocol issues, without whose involvement this supplementary report to the original assessment would not have been possible.

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

A TEAP Task Force has conducted a further study into the distribution and accessibility of ODS banks, where banks are defined as 'consumption not yet emitted', in line with the requests set out in Decision XX/7. The scope of the study covers banks of CFCs, HCFCs and halons, but does not systematically cover the ODS replacements. The reference year has been taken by the Task Force as 2010, representing the earliest point at which any data presented by this report could be readily acted upon. This Interim Report has limited itself to an analysis of developed and developing country banks in order to maintain consistency with other key references on this subject – most notably the 2005 Special Report on Ozone and Climate (SROC) and its Supplement Report.

This latest assessment has concluded that the reachable banks of ODS are distributed as shown in Table ES-1 with levels of effort reflecting the likely ease of access of those banks. Although this varies significantly by sector, the geographic spread of the banks is also important, with ODS banks situated in densely populated (DP) areas being easier to manage than those in sparsely populated (SP) areas.

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

Region	***ODS type***	***Low Effort***	***Medium Effort***	***High Effort***
(all in ktonnes)				
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	-
Global		***1546.52***	***1463.46***	***2349.30***

Since a large proportion of the high effort banks are in insulating foams which are still in use, there is little experience of managing these banks, resulting in limited information on the related costs for recovery and destruction. Accordingly, this Interim Report has focused mostly on costs related to Low Effort and Medium Effort banks.

The outcome of this initial assessment is that costs to manage all low effort banks could reach approximately US $62 billion, while adding medium effort banks would result in total costs approaching US $180 billion. The breakdown of these costs by region and level of effort is summarised in Table ES-2.

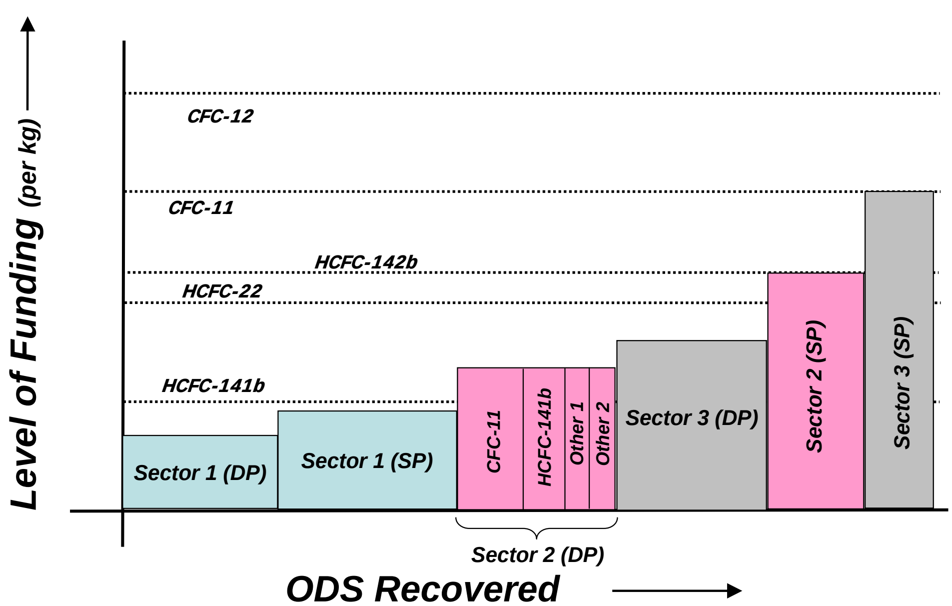
Table ES-2: Summary of Bank Management Costs by Region and Effort

Region	*Low Effort*	*Medium Effort*	*Total*
(US$ billion)			
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
Global	***42.52 - 61.59***	***89.10 - 117.39***	***131.62 - 178.98***

In this interim assessment, no account has yet been taken of the annual flow of decommissioned ODSs into the waste stream and therefore the period over which an investment of the type highlighted in Table ES-2 might be spread. However, it can be realistically assumed that management of ODS banks could take place at least until 2050, based on expected product lifecycles, although, in general terms, the CFC banks will be emitted prior to the HCFC banks.

The Task Force has also assessed the likelihood of being able to finance the recovery and destruction of these ODS banks. Recognising that the global warming potentials of the range of individual ODSs vary, it has been necessary to characterise the banks by substance in order to obtain an average climate benefit arising from bank management in each sector. Such an approach recognises the fact that policy decisions on managing banks are most likely to be taken by sector and region (encompassing both densely populated and sparsely populated sub-divisions) rather than by substance, even though some ODSs within the bank composition may not be cost effective to manage in isolation. Figure ES-1 shows the relationship between sectoral cost and possible revenue, based on a hypothetical carbon price.

Figure ES-1 Relationship between Level of Funding and Cost of Recovery



The diagram illustrates how the carbon funding available will vary with the global warming potential of the substance being recovered and destroyed. It can be seen that the costs for some sectors can be covered no matter what the ODS being recovered is (e.g. Sector 1 (DP)), whereas others cannot. The overall affordability of a particular mix of ODS in a bank will depend on the carbon price available.

Based on the bank compositions assessed and the average global warming potentials derived, carbon prices as high as US $35 per tonne of CO_2 saved may be required to manage all low and medium effort banks. Only if reliable inventories and methodologies are in place will such prices be supported. However, the opportunity would still exist to manage the low effort banks provided that a carbon price of US $15 per tonne of CO_2 saved could be sustained.

The potential policy issues arising from opening up ODS bank management to carbon financing options have been explored. A critical factor in avoiding misuse of this funding mechanism is the traceability of waste streams. There is the potential for this to be ensured by appropriate waste permitting provisions, which already exist in some parts of the world. However, particular care will need to be given to protect against the diversion of ODS continuing to be manufactured for feedstock uses and to ensure that those banks of ODS requiring retention for future use (e.g. halons) are protected.

Since this is still an Interim Report, there remain a number of limitations that Parties may wish the Task Force to address prior to the completion of the Final Report. The following text provides a review of three of these limitations together with a statement of the specific conclusions reached at this stage of the process.

The following three limitations should be noted:

- As noted earlier in the Executive Summary, 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 Report might be to select one or more regional examples.

Notwithstanding these three caveats, the following interim conclusions have been 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_2 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_2 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.

2 Introduction

2.1 TEAP Reports Published

This report is the latest in a series of reports that have progressively dealt with the subject of ODS banks and their potential management. The list of relevant publications is provided below:

- *Task Force on Destruction Technologies* *(2002 and 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 Response to Decision XVIII/12* *(2007)*

At each stage of review, the level of information provided has improved as experience with potential management options has increased. However, much of the data, particularly where they relate to cost, were, and still continue to be, anecdotal to a large extent. Nevertheless, this Report has sought for the first time to take a systematic approach to cost assessment (see section 5). Although the Task Force recognises that this is still preliminary, it is hoped to build on this approach in the period between the Interim and Final Report.

2.2 Data Availability on Banks

The data on the quantities and location of ODS banks have gradually improved over the last ten years. This has been assisted by efforts to validate estimated emissions against atmospheric concentrations, as documented in the TEAP Task Force Report on Emissions Discrepancies (2006).

More recently, work in developing the TEAP Response to Decision XVIII/12 and other bodies of work covering 'practical measures' have continued to assess the likely regional distributions of banks based on consumption history and likely emissions patterns. As covered in more detail within section 4.2, it has even been possible to bring this assessment down to country level, although this level of disaggregation requires interpolation based on metrics such as size of population or GDP.

For the purposes of this Report, it was seen as sufficient to analyse the data based on a regional split between developed and developing countries, at least at this Interim Report stage. Further justification for this rationale is provided in section 3.2 and elsewhere.

2.3 Data Availability on Mitigation Costs

As already noted in section 2.1, the cost data to support this report is still emerging and remains largely anecdotal at this point. There is a particular shortage of information in the commercial refrigeration and stationary air conditioning sectors, although the cost analysis in section 5.3 illustrates that the cost implications of the varying options may not be that great, even though the logistics and required infra-structure may be very different.

Further work will continue between this Interim Report and the publication of the Final Report to hone the data in order to provide the best available assessment of the overall costs of bank management.

2.4 The Process

Decision XX/7 requests that TEAP addresses the following points within its Interim and Final Reports:

"To request the Technology and Economic Assessment Panel to conduct a comprehensive cost-benefit analysis of destroying banks of ODS taking into consideration the relative economic costs and environmental benefits, to the ozone layer and the climate, of destruction versus recycling, reclaiming and re-using such substances. In particular, the report should cover the following elements:

(a) Consolidate all available data on ODS banks and summarize this information identifying the sectors where recovery of ODS is technically and economically feasible;

(b) Respective levels of likely mitigation amounts, based on the categorization of reachable banks at low, medium, and high effort according to substances, sectors, regions, and where possible, sub-regions;

(c) Assess associated benefits and costs of respective classes of banks in terms of ozone depletion potential and Global Warming Potential

(d) Explore the potential "perverse incentives" or other adverse environmental effects that may be associated with certain mitigation strategies, in particular related to recovery and recycling for reuse;

(f) Consider the positive and negative impacts of recovery and destruction of ODS including direct and indirect climate effects

(g) Consider the technical, economic and environmental implications of incentive mechanisms to promote the destruction of surplus ODS

To request the Technology and Economic Assessment Panel to provide an interim report in time for dissemination one month before the 29^{th} meeting of *the Open Ended Working Group and to provide the final report one month before the twenty first meeting of the Parties to the Montreal Protocol."*

The complete text of Decision XX/7 is given in Annex 1.

TEAP established a XX/7 Task Force to assist in the reporting of these issues. The membership of this Task Force is as follows:

Member	***Affiliation and Country***	
Paul Ashford	*TEAP, co-chair FTOC*	*UK*
Julius Banks	*RTOC*	*USA*
Christoph Becker	*RAL Institute*	*D*
Kristian Brüning	*Climate Wedge*	*FIN*
Michael Dunham	*JACO Environmental*	*USA*
Lambert Kuijpers	*TEAP co-chair, RTOC co-chair*	*NL*
Koichi Mizuno	*CTOC*	*J*
Miguel Quintero	*TEAP, co-chair FTOC*	*COL*
Dan Verdonik	*TEAP, co-chair HTOC*	*USA*
Paulo Vodianitskaia	*RTOC*	*BRA*

The Task Force is being co-chaired by Paul Ashford, Lambert Kuijpers and Paulo Vodianitskaia. Biographies including declarations of interest, as well as a brief description of the activities of companies for which certain Task Force members are active, can be found in Annex 2.

The chapters of this Interim Report are ordered to provide appropriate commentary on the matters raised within the text of Decision XX/7. The composition of the Task Force reflects the issues covered and each member was assigned to chapters relevant to their backgrounds and experience in order to provide relevant inputs, guidance and peer review.

An initial overview of the subjects covered and possible interim conclusions were provided to the TEAP at its annual meeting in Agadir in April 2009. A full draft of the Interim Report was then prepared for review by the Task Force and subsequently by the TEAP membership overall.

The final draft of this Interim Report was delivered to the Ozone Secretariat for publication one month prior to the 29th meeting of the Open-ended Working Group to be held in Geneva during July 2009. This meeting will also be accompanied by a specific Workshop on the subject of the Environmentally Sound Management of Banks.

It is expected that a number of further inputs and requests will be received by TEAP as a result of these two events and these will be further considered in the intervening period leading up to the publication of the Final Report in October 2009 ahead of the 21st Meeting of the Parties to the Montreal Protocol.

3 Defining Reachable Banks and Levels of Effort

3.1 Definitions applied to Banks

In order to identify the overall impact of remaining banks of ODS on the ozone layer and the climate, the magnitude and composition of these banks needs to be assessed. In its simplest form, when applied solely to anthropogenic sources, a bank can be defined as:

" the total cumulative global consumption of a substance <u>*minus*</u> *the total cumulative global emissions of that substance"*

This is a deceptively simple definition which hides a number of key supplementary information requirements, such as:

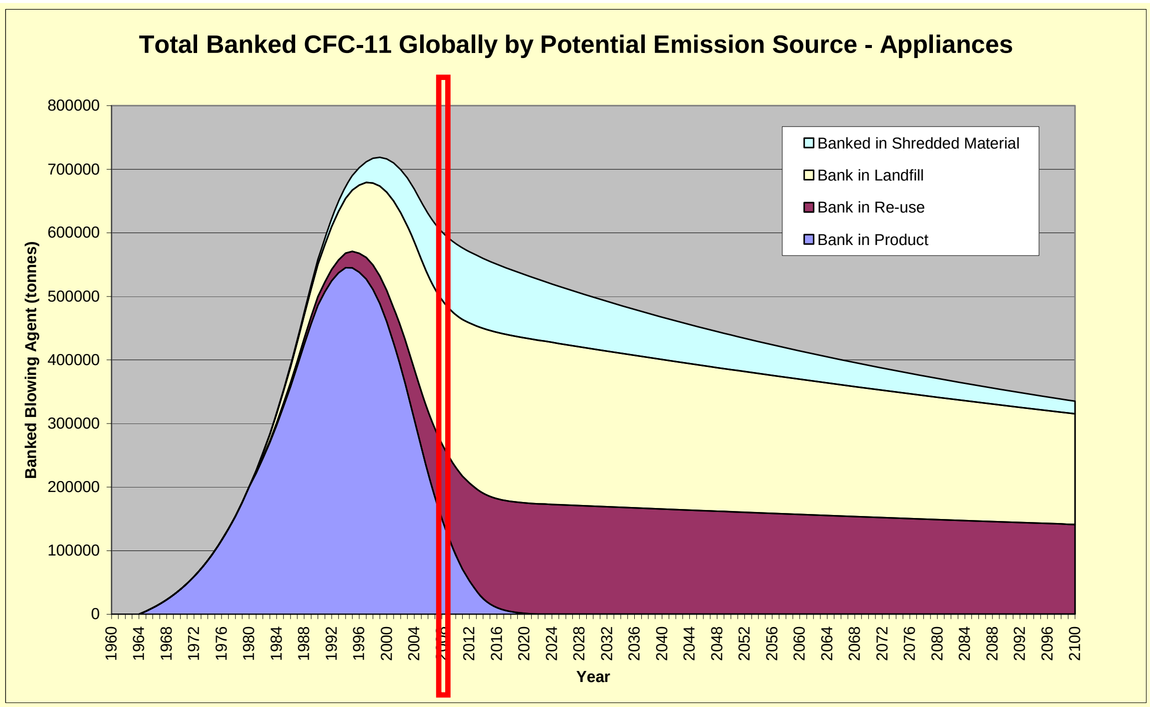
- Historical global and regional use patterns of the substance;
- Emission patterns, both sector of use and by phase of the lifecycle;
- The inter-relationship between consumption within new products/equipment and that required for servicing;
- Assumed lifetimes of the uses over which ODS and their substitutes are applied;
- Any chemical breakdown that might occur in an existing bank of ODS.

All of these are relatively complex assessments and require a systematic approach to the subject. This has resulted in a series of global models being developed in support of this assessment – usually at sectoral level.

For ODS, there are three primary sectors where significant and long-lasting banks can emerge. These are: refrigeration and air-conditioning, closed cell foams and fire protection equipment (typically using halons only). Methyl bromide is not considered to create a bank of its own in this context, since it is either emitted or reacts to form non-volatile reaction products. Efforts to quantify global banks began in the late 1990s and were first considered by TEAP in its 2002 Task Force Report on Collection, Recovery and Storage. As this work continued, the significance of the banks in both size and longevity began to emerge. Not only was this seen to present a concern for ozone recovery but was increasingly seen as a significant additional contributor to climate change.

Although the 2005 IPCC/TEAP Special Report on Ozone and Climate was originally seen to be primarily a study on the impact of ODS alternatives on the climate, it rapidly emerged that the bigger source of impact would arise from the ODS banks themselves. This, in turn, led to the first really systematic assessment of banks, which occurred in the 2003-2004 period[1] as authors prepared for the IPCC/TEAP Report.

One of the many factors that emerged from such assessments was that the distribution of banks and their accessibility varied substantially. Indeed, in some instances, where product lifetimes were relatively short, it emerged that some banked ODS had already entered into the waste stream and were sometimes in landfill. A good example of this, cited in the 2005 TEAP Foams End-of-Life Report were the ODS contained in foams used to insulate domestic refrigerators. The following graphic illustrates the modelled trend.



Although the updates of this model would suggest that the lifetime of domestic refrigerators might be longer than was originally estimated (15 years), the clear message is that ODS banks in this sector need managing sooner rather than later. Even in this underestimated example, the opportunity for recovery and destruction still amounts to in excess of 250,000 tonnes of CFC-11 (more than one billion tonnes of CO_2-eq. emissions).

Conversely, the amount of ODS that may have already reached the waste stream could be as high as 350,000 tonnes of CFC-11 (over 1.6 billion tonnes of CO_2-eq. emissions). Although, these are still technically banks (consumption yet to be emitted), it is recognised that they cannot now be cost-

[1] e.g. Ashford, P., D. Clodic, L. Kuijpers and A. McCulloch: *Emission Profiles from the Foam and Refrigeration Sectors - Comparison with Atmospheric Concentrations*, International Journal of Refrigeration, 2004

effectively recovered and destroyed. At best they can be managed to minimise emissions by such techniques as landfill gas capture and the promotion of conditions which might favour anaerobic degradation. However, for the purposes of this report, these banks already within the waste stream would typically be considered as *unreachable*.

It is the division of the banks in this way which leads to the definition of *reachable* banks as those ODS consumed in application which have neither been emitted nor have entered the waste stream. For most long-lived applications, this represents a significant proportion of the original cumulative consumption. It should be noted that this definition makes no judgement whatsoever on the relatively accessibility of the reachable banks.

3.2 Accessibility: Technical Feasibility, Economic Viability and Levels of Effort

Once the quantities of *reachable* banks have been established the geographic distribution and sectoral location of those banks needs to be considered.

It could be considered that portions of an existing bank for which segregation, recovery and destruction are not technically possible would be defined as *non-reachable*. However, the Task Force has taken the clear view that technical feasibility is not an absolute characteristic of banks, since technological improvements in recovery processes are likely to emerge over the next few years, particularly if the demand for ODS recovery grows from an ozone and climate policy perspective.

The inter-play between technical feasibility and economic viability is also an important factor. It is often stated that "everything has its price" and it is clear that even relatively impractical methods (e.g. manual separation of foam) can become plausible options if the financial benefits of recovery are sufficient to support the effort involved. Such financial benefits can also stimulate the development the technological improvements referred to earlier.

This sense of assessing the <u>effort</u> required for segregation, recovery and destruction processes became the basis of analysis for the 2006 Experts Workshop (and related Report) commissioned by the Executive Committee of the Multilateral Fund. Part of the rationale for communicating in terms of 'effort' reflected the fact that it was too early, at that stage, to consider the specific costs and cost effectiveness of bank management and thereby define the boundaries of economic viability. The Workshop introduced the terms 'low', 'medium' and 'high' specific effort to characterise the accessibility of banks, although there were no formal definitions and the meanings were inferred by illustration. A table from the Workshop Report is included below as Table 3-1 to demonstrate this point.

Table 3-1: Effort Required to Collect Diluted CFCs and Halons (Table 2 in 2006 Expert Workshop Report)

Effort required	Low specific effort	Medium specific effort	High specific effort
CFC in refrigeration applications	X	X	
CFC in foams		X	X
Halons in fire fighting equipment	X	X	

This approach has been carried forward into the language of Decision XX/7 itself, where Clause 7(b) contains a specific request to evaluate:

'Respective levels of likely mitigation amounts, based on the categorization of reachable banks at low, medium, and high effort according to substances, sectors, regions, and where possible, sub-regions'

Again this part of the text avoids direct reference to technical feasibility and economic viability (although they are both mentioned as qualitative qualifiers in Clause 7(a). The Decision also picks-up the theme of economics again in Clause 7(c) where a cost/benefit analysis is inferred against the major environmental criteria of ozone protection and the mitigation of greenhouse gas emissions. This is the subject of Chapter 5 of this report.

3.3 The Impact of Population Density when Considering Levels of Effort

The levels of effort required to manage specific sectoral ODS banks is relatively homogeneous around the world. Accordingly, the <u>effort</u> required to manage the ODS stored in a domestic refrigerator or air conditioner is likely to be roughly the same whether processed in South East Asia or North America even though the overall financial burden of bank management may vary significantly based on labour rates and other local unit costs.

In the case of thermal insulation in building foams, the level of effort may be driven to a degree by building type and methods of construction. However, even in this instance, the product type (e.g. steel-faced panel) will largely dictate the relative cost of segregation, recovery and destruction.

A major departure from this basic tenet on levels of effort occurs when the geographic distribution of ODS banks is spread widely. A relatively diffuse ODS bank can increase the cost of collection, recovery and destruction dramatically, even where the products are relatively easily segregated and managed (e.g. domestic refrigerators). Higher transport distances can also lead to greater potential damage during transit and lower recovery efficiencies as a result.

One factor that tends to act as a suitable proxy for the distribution of ODS banks is population density. The last five years has seen the global urban population exceed the rural population for the first time. Bearing in mind that the relative economic purchasing power of people in urban settings is likely to be higher than their counterparts in rural settings, it would be reasonable to assume that over 50% of all global banks are already situated in urban areas.

Although it would be convenient to use the urban and rural area definitions to drive justification for ODS bank management, the definition of an urban settlement typically applied in many sources is based on a minimum settlement size which is taken, in the UK and in many other countries, as 10,000 inhabitants[2]. Some other countries, however, adopt a population figure as high as 100,000 before classifying a settlement as urban.

Earthtrends[3] conveniently provides an analysis of the populations living in urban settlements of above 100,000 and this can be converted into a percentage by comparing with total population data. However, the Earthtrends data is sourced originally from the World Bank and only covers those regions supported by them (specifically developing countries). In addition, the data is currently only available for the year 2002, which is slightly outdated now, but arguably reflects the purchasing patterns at the height of ODS use. The more general urban/rural data reflects the position in 2005.

Table 3-2 below provides some overview of the outputs.

Table 3-2: Urban and Rural Population and Percentages in Various Regions

Region	***Population in areas with >100,000 people***	***Total Urban Population***	***Total Rural Population***	***% Urban Population***	***% of Population with > 100,000 people***
('000s)					
Asia (excl. ME)	663,893	1,369,206	2,238,409	37.95%	18.40%
Centr. America	73,112	128,101	58,041	68.82%	39.28%
Europe	N/A	525,627	202,762	72.16%	N/A
Middle East/NA	166,136	266,546	185,916	58.91%	36.72%
Oceania	N/A	23,396	9,633	70.84%	N/A
North America	N/A	266,883	63,725	80.72%	N/A
South America	193,224	306,318	68,869	81.64%	51.51%
Sub-Saharan Africa	152,510	264,355	486,918	35.19%	20.30%
Total – Developed	N/A	815,905	276,119	74.71%	N/A
Total – Developing	1,248,895	2,334,527	3,038,154	43.45%	23.25%

[2] 'What is Rural? Commission for Rural Communities, www.ruralcommunities.gov.uk

[3] Earthtrends Searchable Database - Population, Health & Human Well-Being, www.earthtrends.wri.org/

It can be seen that the percentage of urbanisation varies substantially from region-to-region and that there are large variations even amongst developing country regions. The implication would be, for example, that there could be more potential for managing ODS banks in South America than there would be in Asia, where the overall population is a lot more rurally spread. However, the lack of correlation between the regions as defined within the Earthtrends data and the regional definitions used in the respective bank models, makes it difficult to assign ODS bank totals to the regions used by Earthtrends.

There has also been considerable debate amongst the Task Force about what would constitute densely populated areas and what would constitute sparsely populated areas. Although the availability of Earthtrends data for a minimum cut-off figure of 100,000 provides a precise definition, the absence of parallel data for developed countries means that the definition cannot be applied across all banks. In addition, there is concern that the 100,000 population cut-off defines densely populated regions too narrowly and suggests that more of the banks are difficult to access than may be the case in reality. This is particularly so where mobile collection and recovery facilities, or other options can increase the effective accessibility of banks in moderately populated areas.

With these factors in mind, the Task Force has elected to use the urban/rural data provided by Earthtrends as the basis for defining densely populated and sparsely populated areas, despite the fact that the definitions applied are not absolutely consistent around the world. To offset the distortions that might arise from differences in definition across the regions, the Task Force also decided only to divide the regional analysis into developed and developing country components at this stage. A further analysis of regional variations could be triggered at a later point, if required. As a result, the proportion of the population in densely populated areas is seen as approximately 75% in developed countries and around 43.5% in developing countries.

Using this demarcation between densely and sparsely populated regions, the Task Force has evaluated the likely impact of population density on effort required to manage banks. In some instances, but not all, there is seen to be a clear influence related to bank location.

The Task Force has therefore derived a refined version of Table 2 contained in the Report of the Expert Workshop conducted in response to ExCom 48/42. This is shown in Table 3-3 below.

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

Sector	*Low Effort*	*Medium Effort*	*High Effort*
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

4 Current Data on Banks and 2010 Estimates

4.1 Estimates Provided in the 2005 IPCC/TEAP Report and its Supplement Reports

Chapter 3 has already highlighted the importance of the 2005 IPCC/TEAP Special Report on Ozone and Climate (SROC) in the development of a globally integrated set of data on banks and emissions. At that stage, the distinction between reachable and non-reachable banks had not been made in the analysis. However, there was some discussion concerning technical feasibility and economic viability in assessing the potential Mitigation Scenarios arising out of potential policies and measures to reduce emissions.

Since the SROC was primarily a climate report, the dimensions of banks and emissions were expressed largely in terms of tonnes of CO_2-eq. The graphs shown below were some of the primary outputs from this work.

Fig. 4-:1 Historic Data and Projections for 2015 for Banks and Emissions (in Gt CO_2 eq.) from the IPCC/TEAP Report (Fig. SPM-4 in that Report)

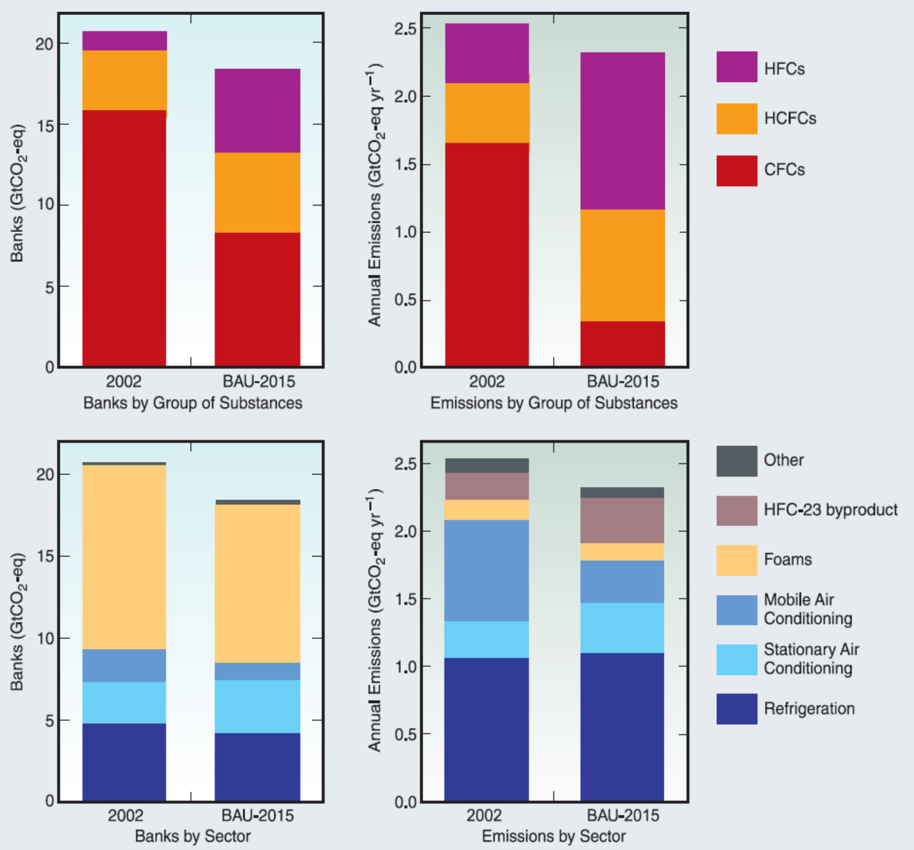


Figure SPM-4. Historic data for 2002 and Business-As-Usual (BAU) projections for 2015 of greenhouse gas CO_2-equivalent banks (left) and direct annual emissions (right), related to the use of CFCs, HCFCs and HFCs. Breakdown per group of greenhouse gases (top) and per emission sector (bottom). 'Other' includes Medical Aerosols, Fire Protection, Non-Medical Aerosols and Solvents. [11.3 and 11.5]

These graphs clearly showed that although blowing agents in foams represented the dominant ODS bank, the emissions arising from them were generally low in comparison with those of refrigerants, where annual leakage (emission) was much more substantial. This had (and has) implications for the focus of mitigation strategies, since it was clear that avoiding emissions in the refrigeration and air conditioning sector would be of higher urgency than managing insulating foams, which remain largely stable over time until removed at end-of-life. These observations have become important components of regional regulations on ODS replacements such as HFCs. The F-Gas Regulation in Europe recognises that the minimisation of emissions is achieved through either the avoidance of HFC use or the adoption rigorous leakage reduction programmes in the *refrigeration and air conditioning sector.*

For the purposes of this report, one of the key messages in managing the remaining ODS banks is that refrigerant banks will decline through emission much more rapidly than blowing agent banks in foam. Therefore actions on refrigerant banks and emissions are generally seen as having higher urgency. The one exception for the foam sector is the use of foams in refrigeration equipment, where life cycles are generally much shorter than in buildings. This had already led to the combined management of ODS blowing agents in foams, where practicable, in parallel with the management of refrigerants (e.g. EC Regulation 2037/2000).

The data presented in the SROC was seen as enlightening, but it was clear that it needed further elaboration to provide meaningful guidance for those primarily tasked with managing ODS banks and their potential impact of ozone layer recovery. This led to the preparation of a Supplement Report by TEAP in late 2005. One of the primary purposes of this study was to express the banks in terms of ozone depleting potential (ODP) as well as actual tonnes of ODS to be managed. The tables below illustrate the outcome of that work. The first table (Table 4-1) illustrates the distribution of banks by substance as at 2002.

Table 4-1: 2002 Banks of Halocarbons per Group of Substances (given as Table 3-2 in the Supplement Report)

Banks 2002	**Product (kt product)**			**ODP (kt ODP)**			**GWP (Mt CO_2-eq)**		
	World	*Non-Art. 5*	*Art. 5*	World	*Non-Art. 5*	*Art. 5*	World	*Non-Art. 5*	*Art. 5*
Halons	165	*80*	*88*	1173	*659*	*514*	531	*330*	*201*
CFCs	2430	*1669*	*760*	2412	*1665*	*747*	15749	*10235*	*5514*
HCFCs	2651	*1997*	*643*	194	*156*	*37*	3841	*2773*	*1062*
HFCs	544	*494*	*49*	0	*0*	*0*	1103	*992*	*36*
PFCs	1	*0*	*0*	0	*0*	*0*	5	*4*	*0*
Total	**5793**	***4241***	***1540***	**3779**	***2480***	***1299***	**21229**	***14334***	***6864***

This data was also presented by sector of application, see Table 4-2.

Table 4-2: 2002 Banks of Halocarbons per Application Sector (given as Table 3-3in the Supplement Report)

Banks 2002	**Product (kt product)**			**ODP (kt ODP)**			**GWP (Mt CO_2-eq)**		
	World	*Non-Art. 5*	*Art. 5*	World	*Non-Art. 5*	*Art. 5*	World	*Non-Art. 5*	*Art. 5*
Refrigeration	971	*406*	*565*	336	*66*	*270*	4751	*1423*	*3328*
Stationary AC	1193	*868*	*325*	134	*86*	*48*	2509	*1721*	*787*
Mobile AC	419	*352*	*67*	150	*108*	*42*	1987	*1500*	*487*
Foams	2996	*2507*	*490*	1978	*1555*	*423*	11270	*9241*	*2029*
Med. Aerosols	12	*9*	*2*	8	*6*	*2*	75	*58*	*17*
Fire Protection	191	*99*	*92*	1174	*659*	*514*	606	*390*	*216*
HFC-23 byprod	-	-	-	-	-	-	-	-	-
N-M Aer./Solv.	12	*0*	*0*	1	*0*	*0*	32	*0*	*0*
Total	**5793**	***4241***	***1540***	**3779**	***2480***	***1299***	**21229**	***14334***	***6864***

Note: Not all banks data could be allocated to regions. For HFC-23 byproduct, non-medical aerosols and solvents no regional breakdown in banks and emissions is available

One of the challenges for both the SROC and its Supplement Report was to project the change in bank size and resulting annual emissions for the year 2015. Although the overall size of refrigerant banks was not seen to change dramatically, the composition of those banks was seen to change significantly, with ODSs (particularly CFCs) replaced by other refrigerants in most applications.

The rate of change sparked interest in determining ODS bank composition for the intervening years. As part of its response to Decision XVIII/12 in 2007, TEAP reported the year-on-year changes in bank size out to 2050, based on a set of regulatory assumptions for consumption up to 2040, as then required under the Montreal Protocol. Decision XIX/6 has since changed the likely profile of bank development in the post 2012 period, but the forecasts, up to and beyond 2012, are still robust.

For the purposes of this Report, the Task Force has decided to adopt 2010 as its reference year for bank data. This choice has been made to recognise the fact that any change in practice resulting from this reporting process, and the related Workshop in Geneva, will not take effect before 2010.

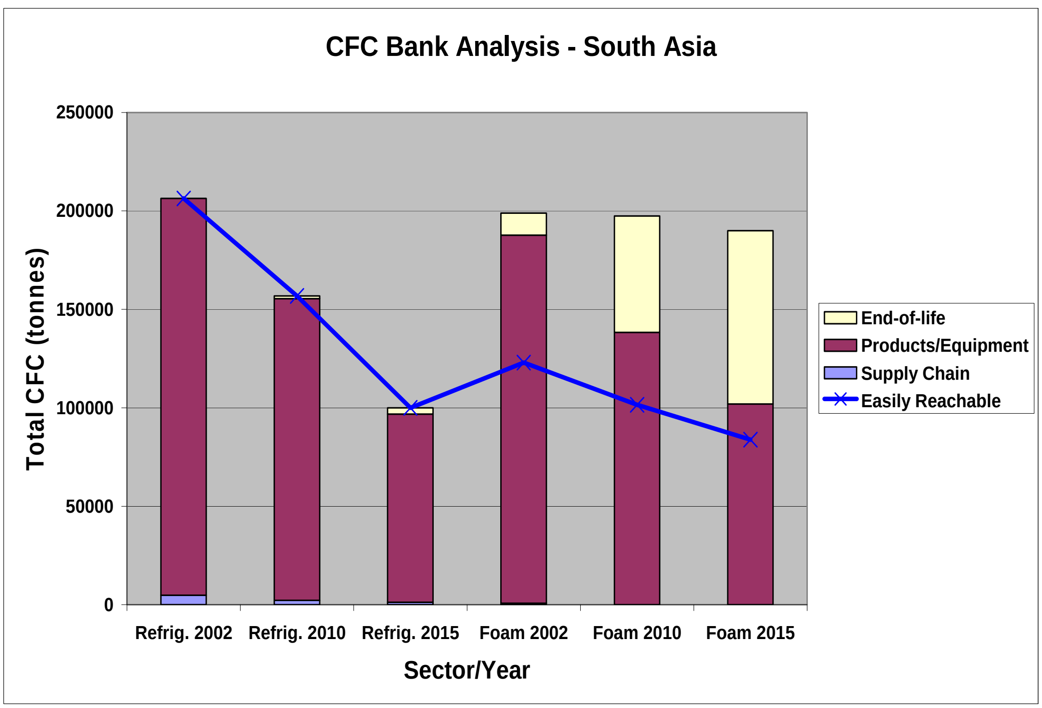
4.2 Further Regional Analysis conducted in support of ExCom Decision 48/42

Apart from lack of bank data in the intervening period between 2002 and 2015, the SROC and its Supplementary Report did not provide a systematic breakdown of banks by region. There was some developed/developing country analysis at sectoral level in some instances, but it was recognised that a further assessment was required.

The Report prepared in support of the Expert Workshop under Executive Committee Decision 48/42 provided an opportunity to develop a more comprehensive overview of bank distribution with reference years of 2002, 2010 and 2015. The data for 2010 is particularly useful for this report in view of the choice of base year already made.

In preparing data for the Expert Workshop, one of the remaining challenges was that the regional divisions applied in the various sectoral models developed since the late 1990s had not always been consistent. The amount of work required to harmonise the models themselves was considered beyond the scope of Decision 48/42. However, since all of the models had the capability to apportion regional banks at country level it was possible to reconstitute regional data to present comparative bank sizes. An example is the graph shown below.

Fig. 4-2: Analysis of the CFC Bank for South Africa giving the Parts for the Refrigeration and Foam Banks that are Easily Reachable (Figure from the Expert Workshop 2006 Report)



In the case of the blowing agent data within **foams**, the further distribution of previous regional bank estimates to country level was achieved through allocation according to national population. Although population data is available and reasonably predictive of the situation at that level, it does not replace bottom-up national assessments, which have the ability to take account of specific national circumstances. The Task Force therefore believes that predicted national bank sizes by allocation will serve as no more than a cross-check to more pertinent national assessments.

With this in mind, the Task Force has refrained from focusing on national data in this Report except in the few cases where the region and the nation coincide (e.g. Japan), preferring to encourage bottom-up assessment wherever possible.

An additional set of constraints on the data generated for the Expert Workshop was that it focused on the distribution of banks in developing countries only and also specifically excluded HCFCs. However, this was not always a constraint of the datasets that supported the Workshop. As an example, the regional bank data for CFC-11 in **foams**, contained estimates for banks in both developed and developing country regions and by sub-sector, as shown below:

Blowing Agent Bank Data - Input Summary

Year	**2010**
Blowing Agent	**CFC-11**

		Europe	N. America	Japan	RODW	Former CEIT	NE Asia	SE Asia	SC Asia	SS Africa	MENA	Latin America	*TOTAL*
Housing Stock ('000)	**(2000)**	205515.7	119986.0	48520.0	10152.0	100934.0	384239.0	119835.0	238897.7	130052.4	74036.1	125886.4	***1558054.2***
Population (million)	**(2000)**	522.7	312.3	126.9	30.1	277.8	1334.4	517.9	1355.1	656.8	371.2	512.4	***6017.69***
End-of-Life	Re-use	32609	18623	4837	3977	8437	26074	5362	3628	2596	22381	26224	***154750***
	Landfill	153476	39954	3312	5009	27957	16710	12876	2181	1532	15290	16349	***294644***
	Shredded	12820	75757	16225	0	0	2463	1098	0	0	1645	1363	***111372***
	Sub total	***198906***	***134334***	***24374***	***8986***	***36393***	***45247***	***19336***	***5809***	***4128***	***39317***	***43936***	***560766***
Rigid PU - Appliance	Dom. Appliance	1298	0	0	14	2871	25579	5195	4758	2198	10112	11280	***63305***
	Other Appliance	242	0	0	5	0	2626	0	346	0	0	544	***3763***
	Reefer	94	0	0	0	0	3634	0	0	0	0	0	***3729***
	Sub total	***1635***	***0***	***0***	***19***	***2871***	***31839***	***5195***	***5104***	***2199***	***10112***	***11823***	***70798***
Rigid PU - Construction	Boardstock	218580	376666	13848	0	0	0	0	0	0	1689	0	***610782***
	Cont. Panel	115671	22538	7615	324	1099	12653	4837	0	0	1953	1541	***168231***
	Disc. Panel	59850	39895	22564	240	1142	12041	17203	1210	334	6956	16095	***177532***
	Spray	34152	39968	20092	490	675	30359	11445	171	281	3789	11719	***153141***
	Block - Pipe	929	306	43	16	0	0	3633	25	53	948	0	***5954***
	Block - Slab	690	309	42	17	0	0	5233	33	76	1369	0	***7771***
	One Component	0	0	0	0	0	0	0	0	0	0	0	***0***
	Pipe-in-Pipe	24932	12979	679	166	2852	38163	0	245	0	0	916	***80931***
	Sub total	***454804***	***492661***	***64882***	***1253***	***5768***	***93216***	***42352***	***1683***	***745***	***16704***	***30271***	***1204340***

For **refrigerants**, the analysis of reachable banks contained within the Expert Workshop Report did not deal concurrently with the factors of regional distribution and sub-sectoral analysis. Therefore the level of analysis available for foam blowing agents (above) was not available for refrigerants. Instead, regional distribution and sub-sector analysis were presented separately.

For the **fire suppression** sector country-level data was presented in the Expert Workshop Report for the year 2004 as follows:

Fig. 4-3: The Banks of halon 1211 in High Consuming Countries (Figure 19 from the Expert Workshop 2006 Report)

Figure 19: Halon 1211 banks in high consuming countries

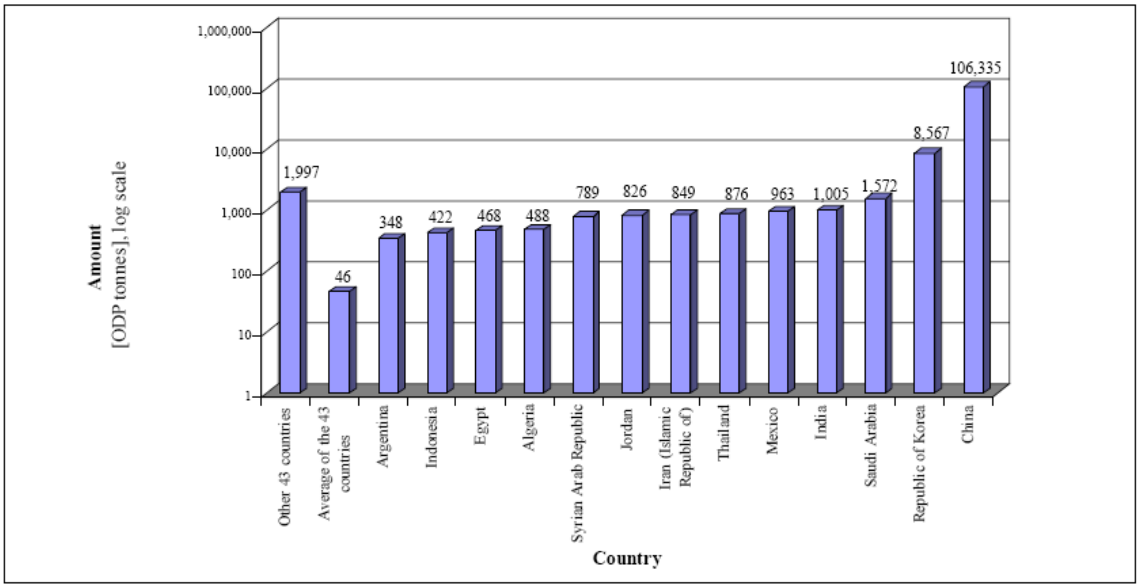
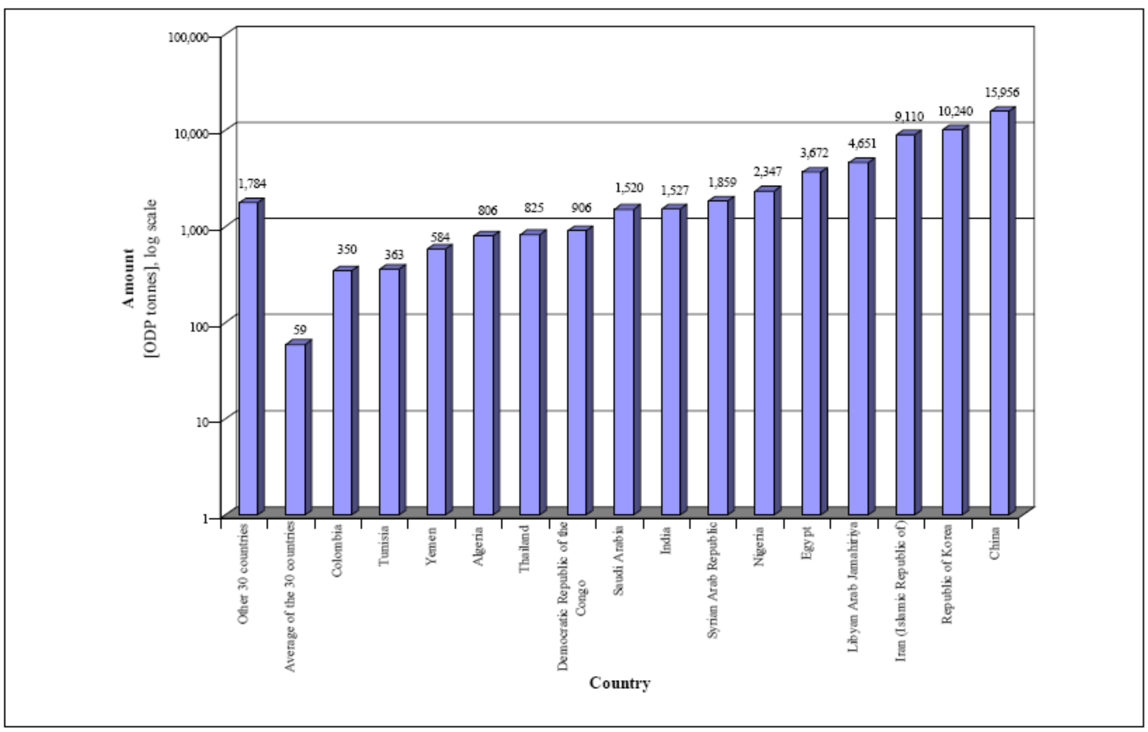


Fig. 4-4: The Banks of halon 1301 in High Consuming Countries (Figure 21 from the Expert Workshop 2006 Report)

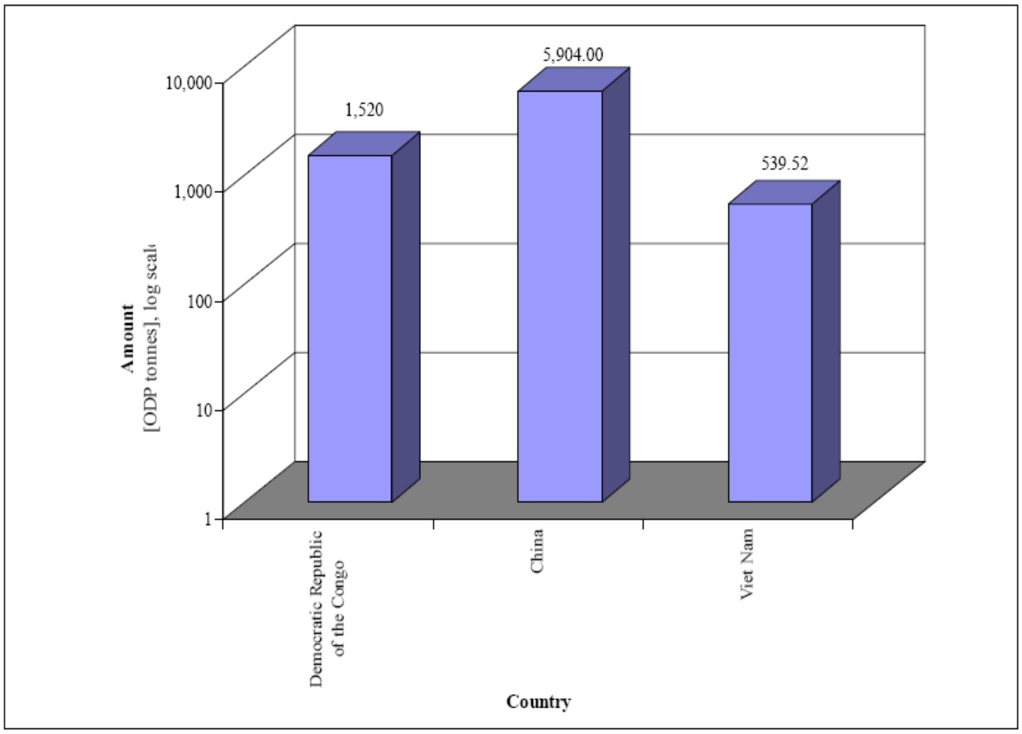
Figure 21: Halon 1301 banks in high consuming countries



Additionally, the Workshop Report introduced data on Halon 2402 for the first time, as shown below in Fig. 4-5.

Fig. 4-5: The Banks of halon 2402 in Three Countries (Figure 23 from the Expert Workshop 2006 Report)

Figure 23: Estimated halon 2402 banks



4.3 Current Analysis

Recognising the need for consistently presented datasets within the analyses required for both of the TEAP Reports required under Decisions XX/7 and XX/8, the respective Task Forces have worked on an analysis that provides bank information for developed and developing country regions by substance and sub-sector. The Tables 4-3 and 4-4 below take this analysis and apply the demarcations of banks into urban and rural sectors to provide estimates of low, medium and high effort banks by regional category.

Table 4-3: Estimates of Low, Medium and High Effort CFC Banks by Regional Category

CFCs by Sector (Developed) – 2010	Low Effort	Medium Effort	High Effort
Domestic Refrigeration – Refrigerant	245	83	
Domestic Refrigeration – Blowing Agent	980	332	
Commercial Refrigeration – Refrigerant	858	291	
Commercial Refrigeration – Blowing Agent	185	63	
Transport Refrigeration – Refrigerant	145		
Transport Refrigeration – Blowing Agent	94		
Industrial Refrigeration – Refrigerant	13,623		
Stationary Air Conditioning – Refrigerant	20,722	7,016	
Mobile Air Conditioning – Refrigerant	30,895	10,487	
Steel-faced Panels – Blowing Agent		200,743	67,954
XPS Foams – Blowing Agent			197,980
PU Boardstock – Blowing Agent			609,094
PU Spray – Blowing Agent			94,702
PU Block – Pipe		967	327
PU Block – Slab		791	268
Other PU Foams – Blowing Agent			38,755
Halon – Fire Suppression	44,323	15,004	
Totals (tonnes)	***112,070***	***235,777***	***1,009,080***
	8.26%	*17.38%*	*74.37%*

CFCs by Sector (Developing) – 2010	Low Effort	Medium Effort	High Effort
Domestic Refrigeration – Refrigerant	11,039	14,366	
Domestic Refrigeration – Blowing Agent	26,936	35,057	
Commercial Refrigeration – Refrigerant	32,366	42,124	
Commercial Refrigeration – Blowing Agent	1,528	1,988	
Transport Refrigeration – Refrigerant	716		
Transport Refrigeration – Blowing Agent	3,635		
Industrial Refrigeration – Refrigerant	12,459		
Stationary Air Conditioning – Refrigerant	10,257	13,350	
Mobile Air Conditioning – Refrigerant	10,408	13,546	
Steel-faced Panels – Blowing Agent		33,484	43,580
XPS Foams – Blowing Agent			1,953
PU Boardstock – Blowing Agent			1,689
PU Spray – Blowing Agent			58,439
PU Block – Pipe		2,024	2,635
PU Block – Slab		2,916	3,796
Other PU Foams – Blowing Agent			42,175
Halon – Fire Suppression	22,245	28,953	
Totals (tonnes)	***131,589***	***187,808***	***154,267***
	27.78%	*39.65%*	*32.57%*

Table 4-4: Estimates of Low, Medium and High Effort HCFC Banks by Regional Category

HCFCs by Sector (Developed) – 2010	Low Effort	Medium Effort	High Effort
Domestic Refrigeration – Refrigerant	0	0	0
Domestic Refrigeration – Blowing Agent	81,571	27,613	
Commercial Refrigeration – Refrigerant	18,301	6,195	
Commercial Refrigeration – Blowing Agent	41,805	14,151	
Transport Refrigeration – Refrigerant	816		
Transport Refrigeration – Blowing Agent	15,371		
Industrial Refrigeration – Refrigerant	59,175		
Stationary Air Conditioning – Refrigerant	402,101	136,115	
Mobile Air Conditioning – Refrigerant	4,282	1,449	
Steel-faced Panels – Blowing Agent		108,922	36,871
XPS Foams – Blowing Agent			393,300
PU Boardstock – Blowing Agent			295,011
PU Spray – Blowing Agent			94,146
PU Block – Pipe		3,042	1,030
PU Block – Slab		7,886	2,670
Other PU Foams – Blowing Agent			15,703
HCFC – Fire Suppression	3,278	1,110	
Totals (tonnes)	***626,700***	***306,483***	***838,731***
	35.37%	*17.30%*	*47.33%*
HCFCs by Sector (Developing) – 2010	**Low Effort**	**Medium Effort**	**High Effort**
Domestic Refrigeration – Refrigerant	0	0	0
Domestic Refrigeration – Blowing Agent	52,083	67,786	
Commercial Refrigeration – Refrigerant	230,716	300,277	
Commercial Refrigeration – Blowing Agent	9,473	12,329	
Transport Refrigeration – Refrigerant	2,345		
Transport Refrigeration – Blowing Agent	15,325		
Industrial Refrigeration – Refrigerant	73,145		
Stationary Air Conditioning – Refrigerant	172,610	224,652	
Mobile Air Conditioning – Refrigerant	7,173	9,335	
Steel-faced Panels – Blowing Agent		25,775	33,547
XPS Foams – Blowing Agent			228,199
PU Boardstock – Blowing Agent			0
PU Spray – Blowing Agent			49,527
PU Block – Pipe			2,433
PU Block – Slab			3,758
Other PU Foams – Blowing Agent			29,756
HCFC – Fire Suppression	410	534	
Totals (tonnes)	***563,281***	***645,446***	***347,219***
	36.20%	*41.48%*	*22.32%*

The analyses show that the effort required to manage the remaining CFC banks in developed countries is high, based on the fact that most of these substances are now present as blowing agents in building foams. In parallel, most refrigeration equipment containing CFCs has apparently already been decommissioned and reached the waste stream by 2010. This is consistent with the assumption of an average lifecycle of 15 years. However, the experience in the field is rather different, with reported product mixes in Europe still being above 80% CFC[4] and, in North America, 75% CFC, 15% glass fibre and 10% HCFC[5]. The only rational explanation for this is that appliances are being used for longer periods (often as secondary refrigerators) in developed countries.

The foam models used to predict bank sizes had foreseen this prospect and the graph in section 3.1 of this Report refers to "re-use" as an end-of-life option, which can effectively be considered as an extended lifetime. However, current refrigerant bank models are not understood to have made a provision for this phenomenon, and may therefore be under-stating the residual CFC bank sizes. On the basis that a typical refrigerator contains approximately four times the amount of blowing agent as it does refrigerant, the adjustments to the CFC bank totals can be envisaged as given in table 4-5 below.

Table 4-5: Adjustments to the CFC Bank Totals from the Re-use of Refrigerators in Developed and Developing Countries

CFCs by Sector (Developed)	***Low Effort***	***Medium Effort***	***High Effort***
Previously estimated totals	112,070	235,777	1,009,080
Domestic refrigerators in re-use – Refrigerant	11,215	3,796	-
Domestic refrigerators in re-use – Blowing Agent	44,860	15,186	-
Total	***168,145***	***254,759***	***1,009,080***
	11.74%	*17.79%*	*70.47%*

CFCs by Sector (Developing)	***Low Effort***	***Medium Effort***	***High Effort***
Previously estimated totals	131,589	187,808	154,267
Domestic refrigerators in re-use – Refrigerant	10,287	13,389	-
Domestic refrigerators in re-use – Blowing Agent	41,149	53,555	-
Total	***183,025***	***254,752***	***154,267***
	30.91%	*43.03%*	*26.06%*

[4] FHA Study of the Treatment of Waste Refrigeration Equipment containing Hydrocarbons – Final Report (2008)

[5] Verbal report from JACO Environmental

This adjustment shows how sensitive the bank estimates are to assumed product lifetimes, especially for shorter lifetime products. With low effort banks boosted globally by over 75,000 tonnes and medium effort banks boosted by over 115,000 tonnes, the additional short-term opportunity is self-evident.

Some commentators have suggested that the bank of remaining CFCs in domestic refrigerators may be even bigger than this, based on assessments of product mix referred to earlier in this section. However, this assumes a relatively gradual transition in that mix over the period to 2020.

For HCFCs, the adjustment is less significant but still worthy of consideration. Table 4-6 illustrates the situation.

Table 4-6: Adjustments to the HCFC Bank Totals from the Re-use of Refrigerators in Developed and Developing Countries

HCFCs by Sector (Developed)	***Low Effort***	***Medium Effort***	***High Effort***
Previously estimated totals	626,700	306,483	838,731
Domestic refrigerators in re-use – Refrigerant	-	-	-
Domestic refrigerators in re-use – Blowing Agent	5,165	1,748	-
Total	***631,865***	***308,231***	***838,731***
	35.52%	*17.33%*	*47.15%*

HCFCs by Sector (Developing)	***Low Effort***	***Medium Effort***	***High Effort***
Previously estimated totals	563,281	645,446	347,219
Domestic refrigerators in re-use – Refrigerant	-	-	-
Domestic refrigerators in re-use – Blowing Agent	210	274	-
Total	***563,491***	***645,720***	***347,219***
	36.20%	*41.49%*	*22.31%*

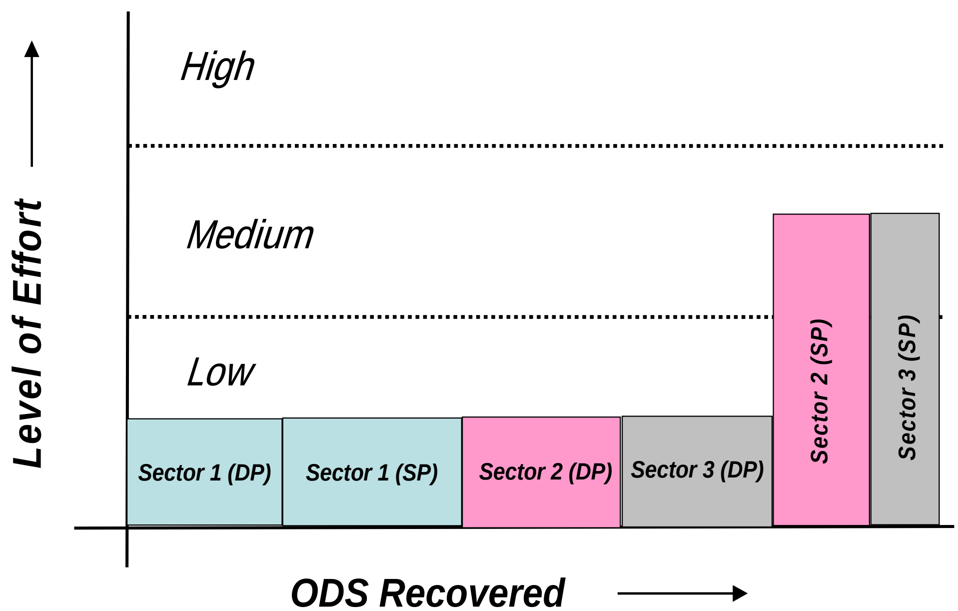
5 Data on Cost of Bank Management

5.1 Variability of Bank Management Costs across the Sectors

One of the purposes of this report, even in its interim form, is to provide comparative cost data for ODS bank management on a sector-by-sector basis. In Chapter 3, the categorisation of the banks into reachable and non-reachable sub-categories and the further characterisation of the reachable banks into levels of effort have all served to provide a basis for this. In Chapter 4, the quantification of banks by levels of effort has been achieved on a sub-sector by sub-sector basis.

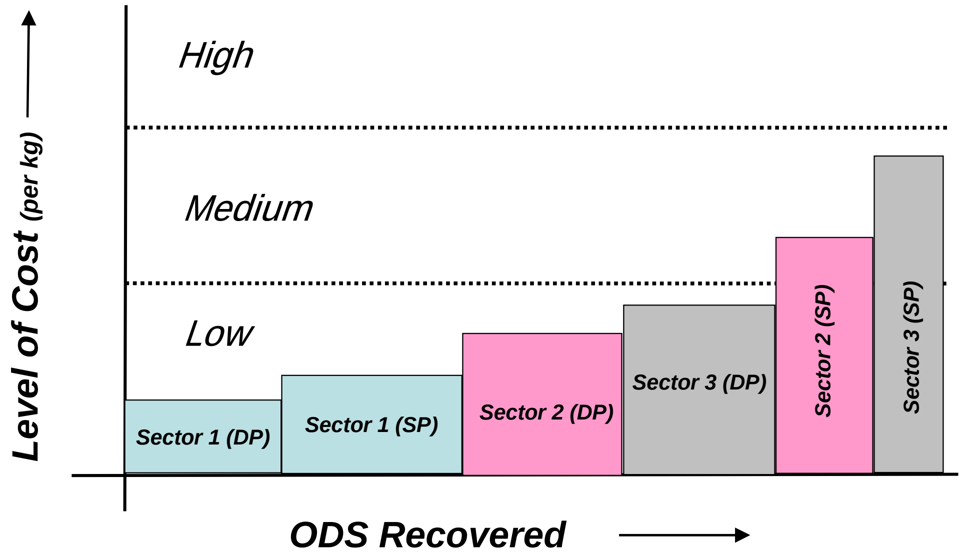
During the development of the Report for the Expert Workshop on Decision 48/42, it was explicitly decided not to refer directly to costs, but to use ‘levels of effort’ as a proxy for the degree of cost involved. An initial analysis on this basis might look as the one given in Fig. 5-1 below.

Fig. 5-1 Examples Concerning the Amounts of ODS Recovered for Certain Levels of Effort (Low, Medium and High) for Densely Populated (DP) and Sparsely Populated (SP) Regions for Three Sectors



This mandate in Decision XX/7 requires the Task Force to go beyond that assessment and start to apply actual costs to the management of these banks. This has been made more possible in recent years because of the growth in the amount of study being attached to this issue. However, it needs to be noted at the outset that the process of gathering reliable cost assessments is still in its infancy and subject to considerable later refinement. It is also likely that unit costs will decrease over-time as techniques are refined. This does not mean that the average cost for bank management will go down overall, since the low-hanging fruit (concentrated sources) is likely to be managed first leaving the longer-lasting, banks in buildings to be managed in a second and more costly step. A typical cost-abatement curve for such an analysis might look as the one given in Fig. 5-2 below.

Fig. 5-2 Examples Concerning the Amounts of ODS Recovered for Certain Cost Levels for Densely Populated (DP) and Sparsely Populated (SP) Regions for Three Sectors



It can be seen immediately, that the transition from 'level of effort' categorisation to cost assessment brings with it a more granular analysis of banks, since each element of the bank now has a different cost allocation. Even this is an over-simplification of the reality, since the cost for sectoral bank management will vary with the cost of local labour and other regional factors, even though the driver of population density will be common to all.

When using the data in this report, therefore, there is a need to understand its limitations. It is a method of ranking the bank management options rather than precisely mapping the expected costs involved.

5.2 Components of the Cost for Bank Management

Although the overall costs can be broken down in a number of differing ways, the Task Force has adopted an approach, which follows the chronological order of steps that are taken to manage a bank. In some instances, this generalised approach will not be relevant for specific banks. For example, where banks are only composed of concentrated sources, there is no need for a segregation step.

The three primary steps covered in this report are:

- Segregation of ODS banks from the waste stream
- Collection and recovery of the ODS banks following segregation
- Destruction of ODS recovered from the ODS-containing products

In some instances, these steps can be combined. For example, direct incineration of insulating foams combines the steps of recovery and destruction into one step, where technically feasible and in compliance with local regulations. However, there will still be a collection cost associated with the transport of the foam following segregation to a destruction facility. In other instances, the same cost category might hide two completely different processes. For example, the relocation of a mobile refrigerator processing unit is a very different step to the shipping of numerous refrigerators to one centralised recovery and destruction unit. However, both classify as a collection cost.

5.2.1 Segregation of Waste

Refrigerators

The segregation of refrigerators from the traditional waste streams has improved dramatically over the last 20 years. This has been driven by two complementary elements:

1. The application of local laws to recover and destroy refrigerants
2. A wider duty of care on manufacturers and users to manage the end-of-life of electrical equipment more carefully.

Both factors have resulted in the availability of refrigerators for further processing. However, in the United States, for example, the ‘further processing’ undertaken was initially to ensure the recovery and ultimate recycling of the steel and other metallic components. This resulted in large numbers of refrigerators disappearing into auto shredders with no particular accountability for the ODS contained in the foams.

This continues to be the case in some regions of the world but, increasingly, the opportunity is being taken to manage the foam component, either through the enactment of appropriate legislation (e.g. Europe and Japan) or by voluntary actions under early retirement schemes being driven primarily by energy efficiency interests.

The relative effectiveness of these various schemes is not a subject for this specific report, but is commented on periodically within other documentation from the UNEP Foams Technical Options Committee.

Insulation Foams in Buildings

From a segregation perspective, these foams create much more of a challenge. The ability to extract foam containing elements from demolition waste depends largely on the form of the products originally used. For example, PU Spray Foams are usually applied directly onto the building substrate and have significant adherence properties. This makes removal complex and often labour-intensive. The losses in the separation of the ODS-containing foam from the substrate can also be a point of concern. The project conducted in Japan by the Japanese Technical Committee on Construction Materials (JTCCM) and reported in 2005 looked hard at this issue and concluded that it was not practical to mandate recovery based on their observations concerning practicality and cost. The Japanese Government therefore favoured a voluntary, incentive-based approach. Notwithstanding this, in March 2009, Tokyo Metropolis announced to start a model project to collect and destroy building insulation foams. This project intends to reduce emissions of fluorocarbons in general.

For other types of product, such as steel-faced panels or PU boardstock, the opportunities for segregation might be greater, depending on the precise application and location of the products. Work in the European Union in support of the re-cast of the Ozone Regulation EC 2037/2000 has investigated this issue in some detail, since consideration was being given to the possibility of some sort of regulatory framework for this ODS bank. The conclusions were that the ability to technically and economically segregate ODS containing waste from buildings depended on two primary factors:

1. the original building practices used within a specific country or region, and
2. the level of demolition waste segregation already required in national law.

This has also led to discussions amongst the Task Force about whether some ODS-containing foams should be considered as reachable at ‘low levels of effort instead of medium’, or ‘medium instead of high’. These considerations are ultimately to be had at local level, but the prevalence of waste segregation laws was not seen as sufficiently widespread to justify anything other than the effort categories already set out in Chapter 3.

5.2.2 Collection and Recovery

The environmental impact of collection and transportation is considered further in Chapter 7, so this section focuses almost entirely on the cost aspects. These are strongly related to the population densities involved and the various shipment distances involved. However, no specific data exists for the comparative average costs of densely and sparsely populated areas. All data quoted in this section are therefore based on averages for a region and/or product type.

The following analysis was assembled for the EC 2037/2000 re-cast process and is based on a number of studies and ad-hoc assessments carried out on blowing agent recovery from refrigerators and steel-faced panels.

Table 5-1: Typical Costs for Parts of the Processes in the Recovery Chain for Blowing Agents from Refrigerators and Steel-faced Panels from Various Sources

Cost analysis – various sources

Tonnage Band	Domestic Appliance	JTCCM (Japan)	Kingspan Panels (trial projects)	Austria Study
Dismantling	-------	€ 55-65	€65-90	Discounted
Sorting	-------	€ 3-4	€ 4-6	Discounted
Transport	€ 25-35	€ 20-25	€5-10	€20-30 (based on steel-faced panels @ €200/te)
Recovery/ Destruction	€ 40-50	€ 20-25	€ 25-35	

Per kg of blowing agent

It can be seen that the figures are calculated for comparative purposes on the cost of collection and recovery 'per kilogram of blowing agent'. This indicates that overall costs for insulating building foams, focusing primarily on steel faced panels, may be twice as high as for domestic refrigerators overall. However, the transport and recovery/ destruction components may be lower in isolation because of the higher packing efficiency for transport purposes and the high concentration of foams (and hence blowing agents) in the mechanical recovery step.

The cost of recovery can vary significantly on the choice of method. Direct incineration of insulation foams can be the least expensive of all options but only if appropriate incinerators (e.g. Municipal Solid Waste or Rotary Kiln Incinerators) are available. Even in these cases, the feed needs to be limited to 5% of the total waste flow if sufficient energy is to be available for adequate destruction of the CFCs (see section 5.2.3). There are anecdotal reports that some waste-to-energy plants in the United States of America have discontinued taking foam waste routinely because of concerns over fluorinerelated corrosion. If this were replicated elsewhere, the cost and logistics penalty of moving to a hazardous waste incinerator network would probably be prohibitive for direct foam incineration.

The other form of collection and recovery from foams is to mechanically extract the blowing agent for re-concentration and onward destruction. This can be done either in a full mechanical recovery plant (as operated typically in Europe and Japan) or in a hybrid approach of manual separation of the foam prior to mechanical separation of the blowing agent from the foam itself. Proponents of the latter have identified the lower energy consumption associated with the initial manual separation step and the potential for job creation in these troubled economic times. Indeed, funding from the stimulus package announced by the current US administration has been quick to reach this sector as a result of its job-creating potential.

For ODS flows that are already concentrated (e.g. bulk refrigerants and halons), the main cost components are simply transport and destruction. However, the major challenge is to avoid venting as a consequence of even these relatively minor cost components. This matter is dealt with further in Chapter 6.

5.2.3 Destruction

UNEP Approved Destruction Technologies and Known Commercial Facilities

Table 5-2: Approved Destruction Processes

	Applicability		
	Concentrated sources		**Dilute sources**
Technology	Annex A, Gp. I, Annex B, Annex C, Gp. I	Halon (Annex A, Gp. II)	Foam
Destruction and removal efficiency (DRE)	99.99%	99.99%	95%
Cement kilns	Approved	*Not approved*	
Liquid injection incineration	Approved	Approved	
Gaseous fume oxidation	Approved	Approved	
Municipal solid waste incineration			Approved
Reactor cracking	Approved	*Not approved*	
Rotary kiln incineration	Approved	Approved	Approved
Argon plasma arc	Approved	Approved	
Inductively coupled radio frequency plasma	Approved	Approved	
Microwave plasma	Approved		
Nitrogen plasma arc	Approved		
Gas phase catalytic dehalogenation	Approved		
Superheated steam reactor	Approved		

(Source: Annex II of the report of the 15th Meeting of the Parties)

The Montreal Protocol has evaluated and approved a number of technologies for the destruction of ozone depleting substances. The TEAP has periodically established Task Forces to review and update these approvals. A current list is maintained within section 3.1 of the 2006 Montreal Protocol Handbook but is reproduced above below for ease of reference.

The last comprehensive review took place in 2005 and incorporated the findings of the Task Force on Foams End-of-Life issues. This review recognised for the first time the distinction between concentrated and dilute sources of ODS. Although Municipal Solid Waste Incineration had been approved for the direct destruction of foam in the original assessment of options in 1995, no criteria for destruction and removal efficiency had been established at that point. This was rectified in 2005 in parallel with the addition of Rotary Kiln Incineration as an approved destruction technology for foams at that time based on good experiences from Japan. In contrast, cement kilns fail to provide a sufficient level of control to warrant approval.

The review of destruction technologies is now routinely handled by the Chemicals Technical Options Committee (CTOC), but no formal review has been commissioned since 1995.

The costs of destruction of concentrated sources of ODS is well-established. In 2002, the Task Force on Destruction Technologies reported costs for CFCs in the range of US$ 3-5/kg and for halons in excess of US$ 7/kg because of the need for slower throughput. These prices related to destruction to in accordance with best practice as subsequently enshrined in the Code of Good Housekeeping contained in section 3.1 of the 2006 Montreal Protocol Handbook. The significance of operating to these standards will be discussed further in Chapter 6.

In the intervening period, prices for unverified CFC destruction has dropped significantly and prices as low as US$ 1-1.5/kg have been reported from some sources. This less stringent market has tended to emerge during the period where the quantification of ODS destroyed has not always been required. However, interest has more recently been rekindled in establishing a basis for quantifying destruction credits, as was the case in the earlier phase of the Montreal Protocol when destruction was more routinely used to offset production, because of the potential of monetising those credits based on their carbon value. Waste processors are now willing to pay the extra for the destruction of ODS by fully documented and verified processes in order to have certified destruction credits, particularly where these can be attributed retrospectively (e.g. under the Chicago Climate Exchange provisions). It has even been reported that some waste handlers are stockpiling ODS in anticipation of a future market for those credits, believing that further attention to both methodologies and registry requirements will increase the value of those credits.

The current price associated with these certified destruction credits is understood to be in the order of US$ 5-6/kg.

Based on a recent investigation of destruction facilities in developing and developed countries, the world destruction facilities are as listed in Table 5-1, although the investigation was incomplete owing to difficulties in obtaining the information. However, it is encouraging that some developing countries have begun to destroy ODS in addition to the existing in developed countries.

Although a thorough survey has not been conducted since the TEAP report in 2002, Table 5-3 presently lists operated "known commercial facilities". ODS destruction facilities in Japan are regulated by the Fluorocarbon Recovery and Destruction Law. Hazardous waste combustors (HWC) in USA permitted by the Resources Conservation and Recovery Act (RCRA) are available to process ODS. Such hazardous waste incineration plants require technical modifications arising from corrosive HF and HBr derived from ODS. These modifications can include:

- Feed rate, flame temperature, and so on in combustion chambers
- HF-resistant refractory lining and binder in combustion chambers
- Upgraded corrosion-resistant scrubbing system
- Monitoring of flue gases/residual ODS, effluent, solid waste

In addition to these changes to the infrastructure, regulatory documents, and personnel training are required for acceptance of ODS. Issues to be covered include:

- Waste storage yard and cylinders/tanks
- ODS handling equipment
- Disposal of solid waste that contains F and Br atoms
- Regulatory permission procedures and documentation

The US E.P.A. reported that 4,332,011 metric tonnes of hazardous wastes were destroyed in the USA in 2005. Based on destruction capacity, the additional capacity for hazardous waste including ODS is estimated at 1,856,576 metric tonnes.

Table 5-3: Number of Known Commercial Destruction Facilities in Countries*

Country	***Number of Known ODS Destruction Facilities in Operation***
1. Argentina	NA
2. Australia	1
3. Austria	1

Country	Number of Known ODS Destruction Facilities in Operation
4. Belgium	2
5. Brazil	6
6. Canada	2
7. Czech Republic	1
8. Denmark	4
9. Estonia	1
10. Finland	1
11. France	2
12. Germany	6
13. Hungary	5
14. Indonesia	1
15. Italy	12
16. Japan	75
17. Netherlands	6
18. Poland	1
19. Russia	3**
20. Slovakia	1
21. Spain	1
22. Sweden	4
23. Switzerland	> 4
24. United Kingdom	2
25. United States	< 10
26. Venezuela	NA

*Source: ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries," May 2008; ** Chemicals Technical Options Committee (CTOC) 2008 Progress Report p.27.

Table 5-4: Known Commercial ODS Destruction Technology Availability*

Category of Technology	Technology	Operating Country	Reported ODS Destruction Capacity	Reported ODS Destruction Price
Hazardous Waste Incineration	Rotary Kiln	Belgium, Brazil, Canada, Czech Republic, Finland, France, Hungary, Russia, Sweden	40 – 545 MT/year	US$4 - 12/kg
	Liquid Injection Incineration	Hungary, Japan, USA	> 13 MT/year	
	Gaseous/Fume Oxidation	Japan	2,600 MT/year	
	Fixed Hearth Units	USA		
	Lightweight Aggregate Kiln	USA		
Destruction with production	Cement Kiln	Indonesia, Japan, USA	600 MT/year	
	Lime Rotary Kiln	Japan		

Category of Technology	Technology	Operating Country	Reported ODS Destruction Capacity	Reported ODS Destruction Price
Destruction Dedicated to ODS	Reactor Cracking	Germany	1,600 MT/year	
	Argon Plasma Arc	Australia, USA	318 – 600 MT/year	US$ 7/kg
	Nitrogen Plasma Arc	Japan		US$ 9/kg
	Inductively Coupled Radio Frequency Plasma	Japan		
	Microwave Plasma	Japan		
	Air Plasma	Sweden	100 MT/year	
	Solid-Phase Alkaline Reactor	Japan		
	Gas-Phase Catalytic Dehalogenation	Japan		US$ 5-7/kg
	Superheated Steam Reactors	Japan		US$ 5kg/kg

*Source: ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries," May 2008, Government of Japan, and others.

Other Destruction Technologies and Facilities

Chemical industries own facilities destroying by-products from fluoro-compounds manufacture. Although some facilities accept and destroy ODS commercially, most facilities may not accept because of hazardous waste storage and handling infrastructure or regulatory permission documentation.

World-wide disposal facilities of PCB destruction were published by UNEP DTIE in 2004[6]. The destruction facilities among disposal facilities are summarised in Table 5-4.

The destruction technologies are high-temperature incineration and non-incineration. The high-temperature incineration includes rotary kiln incinerators, liquid injection incinerators, static kiln incinerators, fluidised bed incinerators, cement kilns. In addition, non-incineration technologies applied are seven technologies: sodium reduction, gas phase chemical reaction/catalytic oxidation/catalytic hydro-dechlorination, base catalysed decomposition (BCD), plasma arc, pyrolysis/gasifiers, advanced oxidation process (electro-oxidation), and hydrothermal oxidation (subcritical water oxidation).

[6] UNEP – Inventory of Worldwide PCB Destruction Capacity – December 2004

Destruction and removal efficiency, DRE, varies in the range of 99% to 99.999999% and 99.99% in average. The capacities of PCB facilities are comparable or larger than those of ODS facilities.

There are four facilities which destroy both ODS and PCB using the same destruction technologies; Clean Harbors, PPM/USA (high temperature incineration), BCD Technologies PTY, LTD/Australia (plasma arc), SPOVO, s.r.o./Czech Republic (at 1,150C) and Valorec Service AG/Switzerland (both by rotary kiln incinerator). Since the capacity of waste is 18,500 tonnes/year, ODS destruction capacity is estimated to be 40 tonnes/year (0.63%).

Prices of PCB treatment are summarised in Table 5-5. Prices are relatively expensive compared to those of ODS.

Table 5-5: Price of PCB Treatment

Type of PCB	***Treatment Price***
PCB oils	30 to 3700 US$/t
Metallic PCB equipment	620 to 3000 US$/t
Non-metallic PCB-contaminated materials	370 and 3870 US$/t
Transformers	175 US$/t to 3000 US$/t
Capacitors	960 to 2300 US$/t
PCB-contaminated solids	310 to 1850 US$/t
PCB-contaminated soil/sediments, residues, sludges	120 to 1850 US$/t

Advantages of the use of PCB destruction facilities are:

- The handling of ODS at PCB facilities is easier than that of PCB or PCB-contaminated materials, although gaseous ODS requires gas leakage prevention.
- Destruction efficiency (DRE) and atmospheric emissions for ODS are achieved more easily.
- Most of the PCB destruction facilities achieve DRE more than 99.999% and atmospheric emissions such as PCDDs/PCDFs are lower than those of ODS destruction.

However, there are some disadvantages

- Currently, there are not enough PCB facilities to destroy all PCBs. World-wide PCB and PCB-contaminated materials and equipment stored for destruction is estimated to be [XXX] tonnes.
- Cost and performance for the destruction operation may bring problems. For example, sodium reduction, base-catalysed decomposition (BCD) may use expensive sodium metal and calcium carbonate. ODS in catalytic destruction may bring about a degradation of poisoning by F atoms.
- Additional costs are required for adaptation for gaseous ODS destruction, such as piping to the reactors and F-atom corrosion protection.

5.3 The Impact of Logistics issues on Unit Recovery Costs

In Chapter 3, the impact of population density on the level of effort required to manage ODS has already been highlighted. In practice, the geographic spread of a bank may tip the balance as to whether an investment is made to manage that bank or not. However, once the investment is made, the effect of geographic spread of the bank will be on the travel costs and other related logistics factors.

Transport costs are a well-studied subject, but offer a relatively complex analysis with a large number of variables. Although rather dated, the EU-funded SoFTiCE Study[7] (1999) provided an estimate of transport costs for new domestic appliances of €1 per tonne/km. For more condensed cargos, such as metal tubes, oil products and electrical equipment, the cost of shipment can reduce to €0.05-0.15 per tonne/km. For general waste streams, the figure is in the order of €0.04-0.06 per tonne/km (5.6p per tonne-mile)[8].

Assuming the maximum weight of a refrigerator to be 100-200 kg, it can be assumed that 5-10 units will be transported for a maximum cost of €1 per km. A range of cost of US $0.15-0.20 per appliance per km would therefore seem appropriate. Where the refrigerator carcasses have been pre-cut, this might reduce to US $0.02-0.04 per appliance per km.

For commercial refrigeration and stationary A/C equipment, it has been assumed that the average weight of a unit is 250 kg and that charge size is in the range of 500g to 2 kg with an average of 1 kg.

For industrial refrigeration, it is assumed that the average charge is 20 kg and that all ODS is recovered on site.

For pre-concentrated shipments of ODS, the shipping costs would probably be as low as US $0.12-0.15 per tonne/km. The implication is that those ODS banks which are already pre-concentrated (e.g. refrigerants and fire suppression agents) will have much lower logistics costs. These costs will be even lower where the quantities of ODS at one location are large (e.g. industrial refrigeration units).

The costs of ODS bank recovery for transport refrigeration is a little difficult to assess, since the transport can travel to the recovery facility. Although, there will be finite transport costs arising from the movement of this equipment, it is assumed to be outside of the scope of this cost assessment.

[7] SoFTiCE - Survey on Freight Transport including Cost Comparison for Europe (1999)

[8] Best Integrated Transport Options for Waste in Scotland (2005)

Returning to the impact of population density on transportation distances and costs, it has been assumed for the sake of this report that average transportation distances in densely populated areas is 50 kilometres, whereas those in sparsely populated areas is 250 kilometres.

Using these assumptions, Table 5-6 has been derived to characterise total costs for each sector of the available bank falling into the low and medium effort categories.

Table 5-6: Unit Costs for Each Sector of the Available Bank Falling into the Low and Medium Effort Categories

Effort Level	*Sector*	*Segregation/ Collection Costs*	*Transport Costs*	*Recovery & Destruction Costs*	*Total Cost*
		(US$ per kg)	*(US$ per kg)*	*(US$ per kg)*	*(US$ per kg)*
Densely Populated (50 km)	Domestic Refrigerators	------	20-30	45-55	65-85
	Commercial Refrigeration	------	5-10	45-55	50-65
	Transport Refrigeration*	------	1-2	10-15	11-17
	Industrial Refrigeration	5-10	0.0025	5	11-16
	Stationary A/C	------	1-2	10-15	11-17
	Mobile A/C	------	1-2	10-15	11-17
	Steel-faced Panels	80-100	10-15	30-40	120-155
	Block – Pipe	10-15	15-20	30-40	55-75
	Block – Slab	80-100	10-15	30-40	120-155
	Fire Protection	5-10	0.005	5	11-16
Sparsely Populated (250 km)	Domestic Refrigerators**	5-10	15-20	45-55	65-85
	Commercial Refrigeration	------	10-15	45-55	55-70
	Industrial Refrigeration	5-10	0.0125	5	11-16
	Stationary A/C	------	5-10	10-15	15-25
	Mobile A/C	------	5-10	10-15	15-25
	Fire Protection	5-10	0.0250	5	11-16

* Refrigerants only

** Assumes that refrigerators are flat-packed prior to shipment

5.4 Impact of Substance-specific Properties on Bank Management Drivers

Chapter 4 provided an analysis of those banks that can be managed at low, medium or high effort. For the purposes of this report, any further cost analysis will be limited to those sectors which fall into the low and medium effort categories. Part of the rationale for this is that there is insufficient technical and cost information on some of the high effort banks to make any realistic assessment of recovery costs at this time. For the most part, those banks are also long-lived and are likely to be available for recovery in a later period, when recovery technologies are more mature.

Table 5-7: Available Banks and Costs Associated with Recovery in Developed Countries (Cumulative Costs are Costs Added for all Sectors)

Effort Level	*Sector*	*Available total ODS*	*% CFC*	*Cost per kg recovered*	*Overall cost of bank management*	*Cumulative Cost*
Developed Countries		*(ktonnes)*		*(US $/ kg)*	*(US$ million)*	*(US$ billion)*
Low	Fire Protection*+	47.60	93.11	11-16	523.6 – 761.6	0.52-0.76
	Industrial Refrigeration	72.80	18.71	11-16	800.8-1164.8	1.32-1.93
	Transport Refrigeration	16.43	1.45	11-17	180.7-279.3	1.51-2.21
	Stationary A/C	422.82	4.90	11-17	4651.0-7187.9	6.16-9.39
	Mobile A/C	35.18	87.83	11-17	387.0-598.1	6.54-9.99
	Commercial Refrigeration	61.15	1.71	50-65	3057.5-3974.8	9.60-13.97
	Domestic Refrigeration	144.04	39.78	65-85	9362.6-12243.4	**18.96-26.21**
Medium	Fire Protection*+	16.11	93.11	11-16	177.2- 257.8	0.18-2.58
	Stationary A/C	143.13	4.90	15-25	2146.9-3578.2	2.32-3.84
	Mobile A/C	11.94	87.83	15-25	179.1-298.5	2.50-4.13
	Commercial Refrigeration	20.70	1.71	55-70	1138.5-1449.0	3.64-5.58
	Block – Pipe	4.01	24.12	55-75	220.6-300.8	3.86-5.88
	Domestic Refrigeration	48.76	39.78	65-85	3169.4-4144.6	7.03-10.03
	Steel-faced Panels	309.67	64.83	120-155	37160.4-47998.9	44.19-58.03
	Block-Slab	8.68	9.12	120-155	1041.6-1345.4	**45.23-59.37**
Total Cumulative Cost for Low and Medium Effort Level						**64.19-85.58**

* Percentages quoted for CFCs are for halons in this case

+ It is important to note that this table is only recognising the cost effectiveness of halon recovery and destruction and is not advocating it. Section 6.3 provides important information on why this could be inappropriate.

When choosing to manage a bank of ODS, it needs to be recognised that a combination of CFCs and HCFCs will be present within both refrigerant and foam banks. The composition of the bank will depend on its age profile, the lifecycle of the products in question and the geographic location. When targeting such banks, it is generally not possible, or at least not cost effective, to preferentially target one substance type over another. Most recovery programmes are sector-specific and adopting a discriminatory, substance-specific, approach would have parallels to operating a selective fishing policy and discarding unwanted fish. Accordingly, when looking at the overall cost effectiveness of programmes, the mix of recovered ODS becomes a key component. Table 5-7 above provides an assessment of the available banks and the costs associated with recovery in developed countries. These figures provide an insight into the cumulative spend required to manage the banks in ascending order of cost in developed countries in accordance with the definitions of low and medium effort set out in Chapter 3.

Table 5-8 provides the same analysis as Table 5-7 for the developing countries.

Table 5-8: Available Banks and Costs Associated with Recovery in Developing Countries (Cumulative Costs are Costs Added for all Sectors)

Effort Level	*Sector*	*Available total ODS*	*% CFC*	*Cost per kg recovered*	*Overall cost of bank management*	*Cumulative Cost*
Developing Countries		*(ktonnes)*		*(US$/ kg)*	*(US$ million)*	*(US$ billion)*
Low	Fire Protection*+	22.65	98.19	11-16	249.1-362.4	0.25-0.36
	Industrial Refrigeration	85.60	14.55	11-16	941.6-1369.6	1.19-1.73
	Transport Refrigeration	22.02	19.76	11-17	242.2-374.3	1.43-2.11
	Stationary A/C	182.87	5.61	11-17	2011.6-3108.8	3.44-5.22
	Mobile A/C	17.58	59.20	11-17	193.4-298.9	3.64-5.51
	Commercial Refrigeration	274.08	12.37	50-65	13704.0-17815.2	17.34-23.33
	Domestic Refrigeration	141.77	63.07	65-85	9215.1-12050.5	**26.56-35.38**
Medium	Fire Protection*+	29.49	98.19	11-16	324.4-471.8	0.32-0.47
	Stationary A/C	238.00	5.61	15-25	3570.0-5950.0	3.89-6.42
	Mobile A/C	22.88	59.20	15-25	343.2-572.0	4.24-6.99
	Commercial Refrigeration	356.72	12.37	55-70	19619.6-24970.4	23.86-31.96
	Block – Pipe	3.89	51.98	55-75	214.0-291.8	24.07-32.26
	Domestic Refrigeration	184.43	63.07	65-85	11988.0-15676.6	36.06-47.93
	Steel-faced Panels	59.26	56.50	120-155	7111.2-9185.3	43.17-57.12
	Block-Slab	5.80	50.25	120-155	696.0-899.0	**43.87-58.02**
Total Cumulative Cost for Low and Medium Effort Level						**70.43-93.40**

* Percentages quoted for CFCs are for halons in this case

+ It is important to note that this table is only recognising the cost effectiveness of halon recovery and destruction and is not advocating it. Section 6.3 provides important information on why this could be inappropriate.

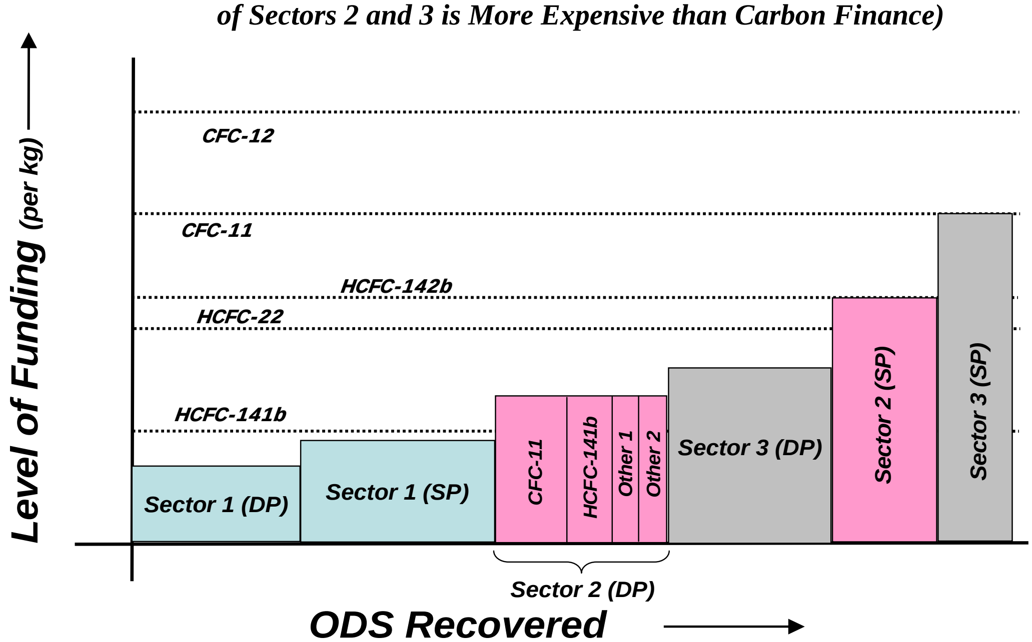
The overall cost of management of the identified ***'low and medium effort'*** banks is ***US $64.19-85.58 billion*** for the developed counties and the equivalent value for the developing countries banks is ***US $70.43-93.40 billion***.

Collectively, the overall cost of management of the identified global ***'low effort'*** banks is ***US $45.52-61.59 billion*** and the equivalent value for ***'medium effort'*** banks is ***US $89.10-117.39 billion***.

Although these are very large numbers in comparison to the investments made by the Montreal Protocol in order to achieve technology transitions, they need to be placed into the context of the costs of achieving climate mitigation. In order to do this, it is necessary to assess the climate benefits that would arise from the management of the banks and, to do this, there is a need to assess the relative global warming potentials of the mix of ODS substances that make up the bank.

The following graph indicates the on-going process of analysis, which occurs when applying a specific carbon price to a series of mitigation measures. The funding available for the avoidance of emissions of each of the key substances is illustrated as follows:

Figure 5-3: Relationship between the Level of Funding and Cost of Recovery (Level of Funding is Highest for CFC-12 and Lowest for HCFC-141b, Showing that Certain HCFC-141b Recovery and Destruction in Parts of Sectors 2 and 3 is More Expensive than Carbon Finance)



It can be seen that the low cost items can be funded from carbon financing even when the ODS emissions avoided relate to lower GWP substances such as HCFC-141b. However, as noted previously, unless policy makers choose to 'discard' the opportunity to recover HCFC-141b, a decision to manage 'Sector 2' in a densely populated area should not exclude the management of the HCFC-141b part of the bank, even though the costs of recovery and destruction may be higher than the recovered carbon finance. In reality, bank management decisions need to be made by sector and not by substance. In order to facilitate this, average GWPs need to be established by sector.

In addition, an estimate needs to be made about the likely carbon price pertaining to this type of programme. This subject is discussed in more detail within Chapter 8, but, by way of example, the following analysis is conducted at an assumed price of US $10 per tonne of CO_2 saved.

The process carried out in the following two tables 5-9 and 5-10 is to compare the costs already derived for ODS bank management with the carbon finance revenues foreseeable. The assessment takes no account of the fact that carbon finance is typically recovered after the emission reductions are achieved. In practice, it would be necessary to have some form of fund to stimulate initial bank management actions and to allow for the reinvestment of early credit proceeds into further projects.

Table 5-9: Costs as Derived for ODS Bank Management Compared to Foreseeable Carbon Finance Revenues for Developed Countries

Effort Level	*Sector*	*Available total ODS*	*Average GWP*	*Overall cost of bank management*	*Carbon Finance @ US$10/ton CO_2*
Developed Countries		*(ktonnes)*		*(US$ million)*	*(US$ billion)*
Low	Fire Protection	47.60	3126	523.6 – 761.6	1.488
	Industrial Refrigeration	72.80	3158	800.8-1164.8	2.299
	Transport Refrigeration	16.43	1880	180.7-279.3	0.309
	Stationary A/C	422.82	1990	4651.0-7187.9	8.414
	Mobile A/C	35.18	9632	387.0-598.1	3.389
	Commercial Refrigeration	61.15	1932	3057.5-3974.8	1.181
	Domestic Refrigeration	144.04	2772	9362.6-12243.4	3.993
	Total				**21.073**
Medium	Fire Protection	16.11	3126	177.2- 257.8	0.504
	Stationary A/C	143.13	1990	2146.9-3578.2	2.848
	Mobile A/C	11.94	9632	179.1-298.5	1.150
	Commercial Refrigeration	20.70	1932	1138.5-1449.0	0.400
	Block – Pipe	4.01	1670	220.6-300.8	0.067
	Domestic Refrigeration	48.76	2772	3169.4-4144.6	1.352
	Steel-faced Panels	309.67	3285	37160.4-47998.9	10.173
	Block-Slab	8.68	1075	1041.6-1345.4	0.093
	Total				**16.587**

Again, this is touched on in Chapter 8 but is more fully addressed in the Ozone Secretariat's paper on funding options submitted as a further part of the response to Decision XX/7.

On the basis of this analysis, it can be deduced that a carbon price of **US $9.00–12.44 per tonne CO_2 saved** would be required to fund the package of all measures included under the 'Low Effort' category for Developed Countries. Clearly, this assessment is highly contingent on the cost assumptions made in the larger air conditioning and refrigeration sectors. It should be noted that, at this interim stage, there remain some significant uncertainties with respect to these particular costs. It is equally clear that there are some obviously profitable activities, which can be used to cross-fund those less lucrative areas such as domestic refrigeration.

Table 5-10: Costs as Derived for ODS Bank Management Compared to Foreseeable Carbon Finance Revenues for Developing Countries

Effort Level	*Sector*	*Available total ODS*	*Average GWP*	*Overall cost of bank management*	*Carbon Finance @ US $10/ton CO_2*
Developing Countries		*(ktonnes)*		*(US$ million)*	*(US$ billion)*
Low	Fire Protection	22.65	3249	249.1-362.4	0.736
	Industrial Refrigeration	85.60	2823	941.6-1369.6	2.416
	Transport Refrigeration	22.02	3189	242.2-374.3	0.702
	Stationary A/C	182.87	2139	2011.6-3108.8	3.912
	Mobile A/C	17.58	7073	193.4-298.9	1.243
	Commercial Refrigeration	274.08	2856	13704.0-17815.2	7.828
	Domestic Refrigeration	141.77	4124	9215.1-12050.5	5.847
	Total				**22.684**
Medium	Fire Protection	29.49	3249	324.4-471.8	0.958
	Stationary A/C	238.00	2139	3570.0-5950.0	5.091
	Mobile A/C	22.88	7073	343.2-572.0	1.618
	Commercial Refrigeration	356.72	2856	19619.6-24970.4	10.188
	Block – Pipe	3.89	2775	214.0-291.8	0.108
	Domestic Refrigeration	184.43	4124	11988.0-15676.6	7.606
	Steel-faced Panels	59.26	2995	7111.2-9185.3	1.775
	Block-Slab	5.80	2706	696.0-899.0	0.157
	Total				**27.501**

For the 'Medium Effort' category, the required carbon price to fully cover the costs of ODS bank management would be in the range of **US $26.45–34.98**

per tonne CO_2 saved. Similar observations can be noted for the mix of measures considered, but the impact of the inclusion of foam construction products is self evident in terms of cost/benefit.

On the basis of this analysis, it can be deduced that a carbon price of **US $11.70–15.60 per tonne CO_2 saved** would be required to fund the package of all measures included under the 'Low Effort' category for developing countries. Although, the proportion of CFC-containing products is typically higher than for developed countries, the bank sizes of key low-cost recovery sectors (e.g. stationary air conditioning) are smaller. Again, this assessment is highly contingent on the cost assumptions made in the larger air conditioning and refrigeration sectors. As for the ODS banks in developing countries there are some obviously profitable activities which can be used to cross-fund those less lucrative areas such as domestic refrigeration.

For the 'Medium Effort' category, the required carbon price to fully cover the costs of ODS bank management would be in the range of **US $15.95–21.10 per tonne CO_2 saved**. This price range is significantly lower than that required for developed countries, primarily because of a higher proportion of CFC-containing products and lower exposure to foam-related construction products, such as steel-faced panels.

6 Policy Issues (including Perverse Incentives)

6.1 Production for Destruction

Considerable concern has been expressed in some quarters about the possibility that incentivising the collection, recovery and destruction of ODS could lead to the potential for additional production. Such production would either occur to offset the prior destruction of materials that might have otherwise been recycled to meet legitimate on-going needs for ODS or, even worse, that through some failure to trace the source of ODSs arriving for destruction, recently manufactured ODS could be being manufactured specifically to gain the destruction credits.

There is particular concern in the case of ODS manufacture for feedstock uses, where the legitimate production of large quantities of ODS will continue long after phase-out for dispersive uses.

The proper evaluation of recycling opportunities is discussed in the next sub-section, leaving the matter of literal production for destruction to be considered here.

Chapter 5 has already made reference to the Code of Good Housekeeping contained in section 3.1 of the 2006 Montreal Protocol Handbook. Part of this Code requires the recipient of ODS for destruction to visit the supplier to ensure that there is awareness of the appropriate delivery requirements. The precise text says:

> *'The facility operator should seek to visit and inspect the proposed sender's stocks and arrangements prior to movement of the first consignment. This is to ensure awareness on the part of the sender of the proper practices and compliance with standards'*

It is clear from this text that the primary purpose is for 'compliance with standards' although, at present, these standards relate more to practices to avoid emissions along the supply-chain than they do confirmation of source. However, there would be nothing to prevent these standards from being extended to cover a 'duty of care' provision which traces source. Indeed, the Code of Good Practice could be expanded at relatively short notice to address this aspect.

However, as with all such standards and codes, success will ultimately be measured in terms of the number of Parties that seek to enforce these standards and codes with legislation. Traceability of waste streams is not an unusual goal in the handling of hazardous wastes and there are a number of precedents for potential permitting schemes from within existing regulatory structures.

Nonetheless, there would be a need to decide where the ultimate duty of care would rest. For destruction projects, project developers[9] must be responsible for tracking ODS intended for destruction from the point of origin and quantifying the emissions reductions and registering them with a greenhouse gas registry. The project developer must also be responsible for providing project data to an independent third party verifier. Destruction technologies should be limited to those recognised by the Parties to the Montreal Protocol. Therefore, the Task Force strongly believes that controls on the issue of destruction credits are best enforced by placing the burden of proof on the project developers themselves through a positive and auditable paper trail.

For reasons already set out in Chapter 5, the Task Force does not believe that it would be possible to enforce a policy that requires destruction facilities to limit themselves to the destruction of ODSs which have already ceased to be produced. In order to prevent a perverse incentive to produce ODS for purposes of destruction, the taskforce recommends that only ODS that have been phased out of production and banned from import in the country where destruction will take place are eligible for destruction credits. The taskforce believes that this approach will offer appropriate flexibility rather than limiting destruction projects to ODS that have been banned globally.

Parties to the Montreal Protocol have licensing systems governing the import of ODS. Projects involving destruction of ODS that are imported in compliance with domestic import regulations should be available as projects for destruction credits. Imports are of major concern when dealing with international treaties governing the transport of waste. For example, limits must be placed on projects involving parties or non-parties to the Basel convention.

Particular care will be necessary to ensure that production for feedstock use is not diverted. This may involve greater accountability for the manufacture of these ODS through some form of permitting.

6.2 Loss of Recycling Opportunities

It is self-evident that where substances are recovered and destroyed, they are lost as potential materials for recycling. The review carried out in this Report deals primarily with recovery processes that identify the substance recovered prior to destruction. Where, these recovered materials are either already in concentrated form or are re-concentrated as part of the recovery process, the option is there to divert them for recycling where appropriate. The only

[9] Project developers are not limited to destruction facilities, and may be any entity that receives credit for an emissions reduction project. Project developers may be the material owner, the destruction facility, logistics provider (e.g. importer) or other technology provider.

situation where this would not be the case, is in the direct destruction of dilute sources, such as the incineration of foams.

In seeking to reach a decision about recycling any recovered material, the quality of that substance would need to be evaluated. Often the recovery of post-consumer waste is accompanied by problems with levels of purity and consistency of supply. Additional reclaim steps may be required that could add cost to the recycled material.

The decision about recycling the product will be dependent on whether the market price will bear the costs of recovery and subsequent reclamation. This, in turn, depends on the supply and demand for virgin material. Since the supply of all ODS is already controlled under the Montreal Protocol, it might be necessary to adjust the Protocol to encourage the uptake of larger quantities of recycled material, where this is viewed as appropriate. However, since supply and demand is usually a localised matter, this may better be adjusted at regional or national level.

In practice, most virgin consumption in ODS is now limited to HCFCs, which, in themselves, offer lower climate benefit when recovered and destroyed than the CFCs they replace. Accordingly, the carbon value of these materials will be lower and will often only meet the costs of recovery. This will make it easier for markets demanding recycled materials to compete with the destruction option. It is unlikely in most cases, however, that the market for recycled materials will be able to cover the primary costs of recovery and reclamation, so destruction and the receipt of credits may be the only option. The Task Force therefore believes that most of the recycling opportunities for ODS have already been established prior to any further action in ODS recovery of the sort considered in this report. The key question is whether the growth of a carbon market for ODS would distort this existing market and, if so, to what effect. This, in turn, will be dictated by the prices that carbon credits of this type reach. Clearly the point to avoid would be where there was a loss of existing recycling streams and increased production of virgin material to offset this. This would necessarily need to be covered under the provisions discussed in section 6.1 on the avoidance of ‘production for destruction’.

In the case where further action on ODS recovery does stimulate a new and competitive supply for recycling, it may be necessary to consider additional controls on supply and use, if it is not desirable to see the use of recycled materials increase. This is typically the case where proven alternatives exist and technology transition would otherwise be favoured. Unless there is good reason to believe otherwise, it needs to be assumed that recycled materials will ultimately be released.

6.3 Bank Retention for Later Use

It is clear from the analysis in section 5.4, that there are a number of sectoral banks where destruction of the substances in question and receipt of related carbon credits could provide significant inappropriate drivers for the immediate ‘management’ of ODS banks. In such cases, it will be necessary to provide suitable safeguards to prevent unwanted destruction.

An obvious example is that of halons, where the Report in response to Decision XIX/16 has highlighted the fact that it is not yet clear if there will be an excess of halon in the future that should be destroyed. In fact, some sectors are predicting shortages (not excesses) of halon 1211 over the next few years. While there are anecdotal reports of small quantities of small quantities of halons too contaminated to be recycled or reclaimed with locally available capabilities, this is not generally the case for the global halon bank. Only in these seemingly isolated cases does it appear that destruction of contaminated halons should be considered from either an ozone and/or climate perspective.

Clearly, the destruction of banks that are actually wanted could have very concerning consequences for long-term existing fire protection applications where cost effective and safe alternatives are not available. For example, halons are needed to support the existing fleet of civil aviation aircraft and will continue to be installed on virtually all new civil aircraft for the foreseeable future.

The true cost of destroying banks of halons that are still needed would either have to include the impact of re-manufacture at some time in the future (destruction for later production!) or the significant cost of prematurely replacing the systems that were reliant on the on-going availability of halons.

One way to consider addressing this may be to introduce a permitting process prior to destruction that would clarify whether the ODS banks should qualify for carbon credits on destruction. Such a regime could be introduced and managed at national level based on the relevance of the banks for future use. A mechanism of this type could also be used to intervene in situations where recycling of materials needed to be boosted as potentially envisaged in section 6.2.

6.4 ODS Transformation

Another potential use for recovered ODS is as a feedstock for other fluorinated chemicals. There have been considerable recent developments in this area, an example of which is described below.

The University of Newcastle (New South Wales), Australia has developed a patented, closed-loop process to convert ODS into environmentally benign, usable products. A pilot plant using the process has demonstrated 99.99%

conversion of both halon 1211 and halon 1301, with production of 1,1difluoroethylene, also known as vinylidene difluoride (VDF). Commercial-scale testing on CFC-11 and CFC-12 is scheduled to be completed, and data submitted for TEAP review, in the latter part of 2009.

As the Task Force currently understands it, the technology includes four main processes:

- Reaction of fluorochemical with methane at temperatures in the range of 825 C in an oxygen-free, non-catalytic environment at a residence time of 0.35 seconds;
- Energy recovery;
- Removal of soot , tar, and other condensables;
- Removal of acidic by-products.

Compared with incineration and other destruction technologies, the Newcastle conversion process is understood to require relatively minimal energy input, although this is yet to be fully quantified. Besides VDF, the process produces only calcium and fluoride salts that can also be re-used. Because no oxygen is introduced, there is no dioxin or furan production.

Operating costs for the process at commercial scale are estimated to be less than US $1 per kg of halon or CFC fed into the reactor for conversion. Another major advantage to the technology is that the process units, along with analytical instruments, can be transported and assembled on location, with minimal environmental footprint. This will allow for on-site ODS destruction/conversion where surplus ODS is aggregated and in areas remote from transportation hubs and conventional destruction facilities.

7 Environmental Impacts of Recovery and Destruction

7.1 Recovery and Destruction – Transport Aspects

The environmental impacts of land transport have been well studied by a number of sources. McKinnon produced the graph given in Fig. 7-1 in a recent publication[10] to show the relative impacts of transport options.

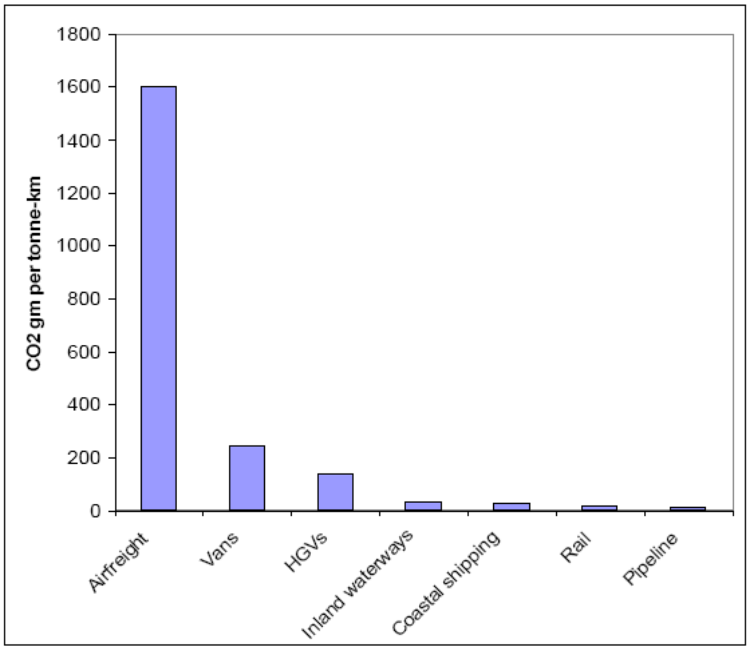


Fig. 7-1: Typical CO2 Emissions for Various Transport Options (McKinnon)

Individual companies have also been mapping the average emissions from road freight movements in order to estimate their own carbon footprints. Adidas produced a figure of 147g CO_2 per km per tonne, which is largely comparable with the McKinnon data above.

On the basis that the weight of an average refrigerator would be in the range of 100-200 kg, it would be reasonable to suggest that the carbon footprint of shipping one refrigerator one kilometre would be in the order of 15-30g CO_2 per unit per kilometre.

However, a further factor to consider here is the volume-to-weight ratio, which tends to be high for products designed for storage. This would mean that more freight transport would be required per tonne of freight than these averages would suggest <u>unless</u> the refrigerators are cut into flat panels before

[10] Carbon dioxide emissions from Freight Transport – An analysis of UK data (2007)

shipment. This step adds cost but improves the efficiency of subsequent shipment. The Building Research Establishment (BRE) in the UK conducted a study[11] for DEFRA in 2002 on the CFC releases associated with taking such steps and concluded that about 3g of CFC-11 was lost through the cutting process.
A figure of $7g/m^2$ was generated from the same study for the cutting down of cold storage panels to allow for easier shipment. Since the global warming potential of CFC-11 is approximately 4680, the loss of blowing agent is still significant in the context of fuel emissions and the case for cutting refrigerators and foam-filled panels up is more one of logistics and economics than one of environmental probity.

7.2 Recovery and Destruction - Energy and Pollutants

Energy

For concentrated sources, the main energy considerations related to the destruction process itself. There is considerable existing documentation on the various destruction options and the Report of the Task Force on Destruction Technologies (TFDT) in 2002 gives a good, if qualitative, overview of the choices available. In general plasma destruction technologies are seen as highly energy intensive in comparison with other options. Technologies such as Gas Phase Catalytic De-halogenation (GPCD) processes are seen as much more energy efficient, while retaining high conversion rates and low levels of pollutants, with the exception of halide salts which arise in the liquid effluent. Probably the main drawback with GPCD is the cost, which tends to be higher than most other processes despite the lower energy consumption.

For dilute sources, the situation is more complex. There are two basic approaches to the management of destruction of ODSs from such sources. These are:

- Destruction of the ODS-containing article in totality through incineration or other means
- Recovery of the ODS from the article and re-concentration prior to destruction

In practice, the comparative energy profile for each option depends on the article in which the ODS is contained. Indeed, there may be hybrids in certain instances.

[11] Cutting of Fridges – Estimating CFC releases & recommended best practice Test Report 208329 (2002)

A good example is the handling of refrigerators. Some mechanical recovery plants handle the total carcass of a refrigerator in one step. This requires the shredder to deal with metals, foams and plastics all at the same time in order to extract the ODS. Monitoring of such plants has suggested that the energy consumption to handle each unit could be as high as 35 kWh.

An alternative approach is to manually separate the foam from the other plastic and metal components of the refrigerator before shredding the foam separately and extracting the blowing agent. Initial estimates suggest that this approach might consume as little as 5 kWh per unit, but, of course, carries with it a higher labour cost.

Where foam can be separated and transported easily to appropriate facilities, the calorific value of the foam itself can be exploited to provide a positive energy gain. However, waste-to-energy plants are not usually sufficiently well controlled to destroy ODS reliably and the blowing agent therefore needs to be separated out first.

For Municipal Solid Waste Incinerators and Rotary Kilns, the controls are typically sufficient to avoid the need for prior extraction of blowing agents and this therefore bypasses the need to consume the additional energy on this step.

However, there is some evidence to suggest that attack from fluorinated gases can be a problem, particularly where blowing agents are not removed prior to the incineration step.

Other Pollutants

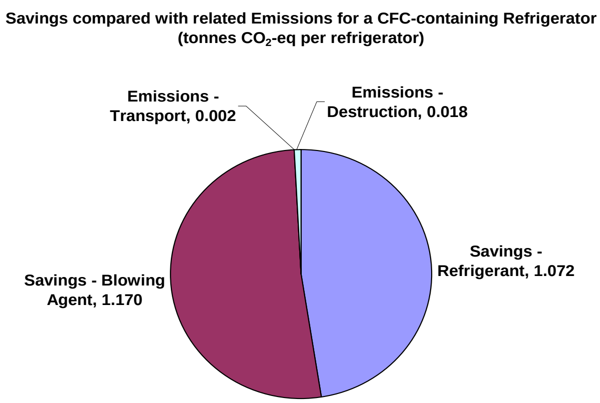
As always, when dealing with halogenated chemicals, there is a risk of the generation of dioxins and other fluorinated and chlorinated pollutants as a result of incomplete combustion. For this reason, the levels of such by-products became a clear point of assessment in the approval of destruction technologies in the 1995 review and thereafter.

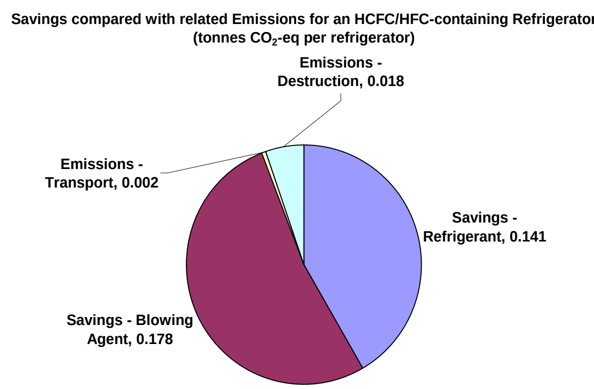
The Task Force therefore believes that adherence to the use of only those technologies approved for the destruction of ODSs under the Montreal Protocol will ensure that the release of pollutants is minimised. The 2002 TFDT Report provides a good overview of the maximum levels of pollutants expected from specific technologies.

Ironically, it may be that the renewed interest in only using approved technologies to ensure the generation of certified destruction credits will reduce stack emissions when compared with the period when destruction was simply carried out at least cost.

7.3 Summarising the Climate Impact of Collection, Recovery and Destruction

Even with the most energy intensive forms of collection, recovery and destruction, the impacts from transport and onward processing are low compared with the climate benefits of ODS emissions avoidance. On the assumption that a minimum of 100g of refrigerant emission and 250g of blowing agent is avoided, the graph below shows the respective contributions for CFC-containing and HCFC/HFC-containing refrigerators.





8 Incentives and Potential Funding Mechanisms

8.1 Carbon Markets: Relationships between Voluntary and Compliance

This Report is not intended to address the subject of carbon finance in detail, since it is being addressed in parallel within a number of other contributions to Decision XX/7, including the report from the Ozone Secretariat and also the proceedings of the forthcoming workshop on ODS bank management. However, it is important that a number of principles are covered here to provide appropriate context in light of the preliminary findings of this Report.

At present, the climate benefits arising from ODS destruction are only just being recognised within the carbon markets. Since, ozone depleting substances are not currently included within the basket of greenhouse gases controlled by the Kyoto Protocol, a reduction of such ODS gases can not provide an offset against compliance targets, as would be the case, for example, with HFCs. Nevertheless, there are a number of actors in the carbon arena who are seeing the potential benefit of providing an incentive for ODS destruction.

The voluntary carbon market currently acts as a focal point for those with an interest in crediting the recovery and destruction of ODS banks through carbon markets. The principle of the voluntary market is that individuals, companies and other institutions without any compliance obligations are voluntarily seeking to mitigate their own carbon footprints through the purchasing and subsequent retirement of carbon credits. The reasons for undertaking voluntary GHG emissions mitigation varies greatly between individuals, companies and/or institutions. Some act out of environmental concern, others out of commercial interest in a “green or carbon-neutral product” and for some companies the voluntary market has provided a first inroad into carbon trading The ability to claim that the net impact of their carbon footprint has been reduced or completely negated offers a variety of very specific benefits, sometimes skeptically referred to as ‘bragging rights’.

The voluntary market does not restrict operators to a specific type of carbon credit. Consequently, the market was quick to meet a growing demand for carbon credits that came from outside of the project boundaries set by accords and rules under the Kyoto Protocol. These type of projects supply a large part of the offsets for voluntary emission reduction programmes. Critics of the voluntary market often point out that the supply of credits can act as a discouragement to the wider requirement to reduce emissions. This is a valid observation, although responsible entities will always seek to reduce their own footprint before relying on offsets to negate the remaining emissions.

The quality of the credits purchased is a fundamental factor in the utility value of a voluntary credit. Credits from projects based on poorly defined methodologies or based on inadequate verification will be of little real value and even result in destruction of wealth e.g. through negative publicity, The core factor underpinning quality is the methodology used for project validation and the registry system used to account and manage credits. These aspects will be discussed further in Section 8.2. ODS projects are an emerging addition to the roster of voluntary market projects and these two core aspects are yet to be established for this project type. Therefore only very few trades have taken place, all of which have been at prices below $5 per tonne of CO_2 saved.

Although ODS are not currently included in any compliance trading schemes, the prospect of a future inclusion of ODS projects as an offset source is nurturing a pre-compliance market in ODS credits. At international level, the scope of Kyoto could, theoretically be expanded both geographically, and in terms of substances covered, for future commitment periods, allowing for the use of ODS credits in CDM. On a regional or national level, e.g. in the US, new legislation targeting GHGs could also establish a compliance market for ODS credits.

Alternatively, as another form of pre-compliance market, an interim cap could be introduced on ODS emitters/holders to align the markets prior to later inclusion in global cap in future Kyoto commitment periods, for example. Indeed, there are a number of emerging national and state level ‘cap and trade’ schemes within non-Kyoto signatory countries that are acting as a prelude to possible Kyoto entry. Even without Kyoto endorsement, these are still legally binding in their own territories and would create fully fledged compliance markets in many cases. These regional schemes, must decide whether ODSs should be included in the greenhouse gases covered by the scheme and whether ODS emissions are targeted through a cap or through a crediting system. In California, for example, it now seems likely that they will be included. National and regional decisions on ODS regulation could have significant bearing on the future global pricing possibilities for ODS credits, as well as the requirements for the appropriate methodologies and registries that underpin the process.

8.2 Registries and Methodologies

Although the Montreal Protocol community may occasionally take it for granted, information about the amount and global distribution of ODSs in terms of consumption patterns (past and present), banks and emissions is probably better studied than for any other greenhouse gas considered within climate policy. This provides a significant starting point and an opportunity to develop and manage a global registry of existing ODS banks against which ODS bank management and destruction projects can be mapped.

This risk of proceeding without such a global registry is that ODS destruction is not recorded on a consistent basis. One of the persistent criticisms of the voluntary market, in general, has been the lack of a transparent registry function to track the registration, transfer and retirement of voluntary credits. Although the Voluntary Carbon Standard (VCS) and other key actors in the voluntary sector are have made significant strides to plug this gap, the reputational damage has already taken place. In a similar fashion, the risk with the uncontrolled (or unmonitored) destruction of ODS is that this experience will be replicated. The analysis in Section 5.4 shows that even a carbon price of $5 per tonne of CO_2 saved would be sufficient to support some bank management processes. Should these activities proceed in the near future without the necessary monitoring and verification, it would become increasingly difficult to assess retrospectively what had been done at the time. It is therefore important that any voluntary destruction of ODS gases, in the absence of any centralized ODS registry, ensures full traceability of projects and gases in existing and emerging registry frameworks.

Moreover, it is clear from Section 5.4, that only the ‘low hanging fruit’ would be viable for management at the voluntary market carbon price. If these were addressed preferentially and the profits arising were dispersed, it would not be possible to re-invest them for the management of the more challenging banks. The value of establishing an appropriate registry and associated methodologies is that it sets the quality of any credits arising, with impact on the demand for these, and ultimately on their expected price: - the better the registry and the methodologies, the greater the price. It is clear from the wider evaluation of ODS bank management options in Section 5.4, that a carbon price in excess of $15 per tonne of CO_2 saved would be required to manage the ‘Low Effort’ banks. Of course, not all of these banks are available for recovery and destruction today, and it can be expected that the overall carbon price will continue to increase with time, as the costs of adaptation become clearer.

Work on methodologies is already underway and a number of promising options are now emerging, particularly in the area of domestic refrigerator management.

8.3 The Impact of Regulation

The carbon market is underpinned by a principle that seeks to ensure that carbon finance only benefits projects that need an extra monetary incentive to make the project viable. This is known as the principle of ‘additionality’. Accordingly, where regulation already requires a certain action to be taken with respect to ODS bank management, no perceived benefit would be seen to arise from additional carbon finance and the project would be deemed ineligible unless it delivered something incremental (e.g. a high level of recovery than mandated).

The successful application of any such regulations requires an appropriately robust approach to enforcement, particularly where the costs of ODS bank management are high (as illustrated in Section 5.4). A poorly enforced regulation can lead to less recovery and destruction than a properly incentivised voluntary approach. Accordingly, those seeking to initiate regulation in this area need to be reasonably certain that the tools are in place to police the implementation of the regulation.

The United Nations Framework Convention on Climate Change (UNFCCC) foresaw that this concern might prevent developing countries from implementing appropriate national legislation and therefore introduced a moratorium under the Clean Development Mechanism (CDM) for all legislation passed later than 2001. This has meant that Developing Countries have not subsequently jeopardised their claim to additionality by its subsequent regulatory approach on greenhouse gases.

In the case of ODS banks, it would need an additional moratorium of this type, agreeable to the carbon markets and other relevant stakeholders, to maintain ‘additionality’ while implementing relevant regulations to provide a framework for the management of the ODS banks.

8.4 Developed versus Developing Country Aspects

The costs of managing ODS banks have been identified in Section 5.4 and some significant differences in both the composition of the banks and their distribution have been noted for Developing Countries. These partly relate to the age of the banks and the historic economic development of the various regions and the prevailing climates.

It is often the case that efforts to manage ODS banks coincide with other market transformation programmes. The need to improve the energy efficiency of building components (e.g. chillers) or the domestic refrigerator stock can combine to provide an added incentive to ODS bank management, since costs can be shared. However, this cost-sharing arrangement brings with it the need to manage a co-financing process, which can be complex.

The Implementing Agencies under the Montreal Protocol are typically also involved in such projects run under the Global Environment Facility (GEF) and can act as a focal point for such co-ordination. However, early experience shows that these projects can become unwieldy and less appropriate for carbon finance in the traditional way. Therefore indirect linkages to the carbon market (perhaps a programmatic level) might be a more appropriate way forward in many cases.

For developed countries the issues are somewhat different. In some instances regulatory frameworks already exist for ODS bank management and might preclude the development of a supporting carbon market (voluntary or pre-compliance) without further intervention. This might need significant further time to resolve and the early launch of a fully fledged voluntary market might be counter-productive unless adequate controls are in place. Indeed, this would initiate the presence of the voluntary market in regions where it is otherwise precluded by the existing compliance market.

The interest of all might be best served by taking a measured approach at international level to the linkages with existing and emerging carbon markets in order to gain the best level of financial support for the management of ODS banks and to retain control of the process.

9 Interim Conclusions

Although this is an Interim Report, the Task Force has attempted to address the full scope of the requests to the TEAP within Decision XX/7 in order to provide a balanced basis for further discussion and development. However, the following three limitations should be noted:

- 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 Report might be to select one or more regional examples.

Notwithstanding these three caveats, the following interim conclusions have been 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_2 saved to ensure their effective management.
- The ‘Medium Effort’ banks would ultimately require a carbon price in excess of US $35 per tonne of CO_2 saved to ensure their effective management

- 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.

Annex 1 Decision XX/7: Environmentally sound management of banks of ozone-depleting substances

1. To invite Parties, international funding agencies, including the Multilateral Fund and the Global Environment Facility, and other interested agents to enable practical solutions for the purpose of gaining better knowledge on mitigating ozone-depleting substance emissions and destroying ozone-depleting substance banks, and on costs related to the collection, transportation, storage and destruction of ozone depleting substances, notably in Parties operating under paragraph 1 of Article 5 of the Montreal Protocol;

2. To request the Executive Committee of the Multilateral Fund to consider as a matter of urgency commencing pilot projects that may cover the collection, transport, storage and destruction of ozone-depleting substances. As an initial priority, the Executive Committee might consider projects with a focus on assembled stocks of ozone-depleting substances with high net global warming potential, in a representative sample of regionally diverse Parties operating under paragraph 1 of Article 5. It is understood that this initial priority would not preclude the initiation of other types of pilot projects, including on halons and carbon tetrachloride, should these have an important demonstration value. In addition to protecting the ozone layer, these projects will seek to generate practical data and experience on management and financing modalities, achieve climate benefits, and would explore opportunities to leverage co-financing;

3. To encourage Parties to develop or consider further improvements in the implementation of national and/or regional legislative strategies and other measures that prevent the venting, leakage or emission of ozone-depleting substances by ensuring:

(a) Proper recovery of ozone-depleting substances from equipment containing ozone-depleting substances, during servicing, use and at end of life, where possible in applications such as refrigeration, air conditioning, heat pumps, fire protection, solvents and process agents;

(b) The use of best practices and performance standards to prevent ozone-depleting substance emissions at the end of the product life cycle, whether by recovery, recycling, reclamation, reuse as feedstock or destruction;

4. To encourage all Parties to develop or consider improvements in national or regional strategies for the management of banks, including provisions to combat illegal trade by applying measures listed in decision XIX/12;

5. To invite Parties to submit their strategies and subsequent updates to the Ozone Secretariat as soon as possible for the purpose of sharing information and experiences, including with interested stakeholders of other multilateral environmental agreements, such as the United Nations Framework Convention on Climate Change and its Kyoto Protocol and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. The strategies will be placed on the Ozone Secretariat website, which will be updated regularly;

6. To note that any project implemented pursuant to the present decision when applicable should be done in conformity with national, regional, and/or international requirements, such as those mandated by the Basel Convention and Rotterdam Convention;

7. To request the Technology and Economic Assessment Panel to conduct a comprehensive cost-benefit analysis of destroying banks of ozone-depleting substances taking into consideration the relative economic costs and environmental benefits, to the ozone layer and the climate, of destruction versus recycling, reclaiming and reusing such substances. In particular, the report should cover the following elements:

(a) Consolidation of all available data on ozone-depleting substance banks and summary of this information identifying the sectors where recovery of ozone-depleting substances is technically and economically feasible;

(b) Respective levels of likely mitigation amounts, based on the categorization of reachable banks at low, medium, and high effort according to substances, sectors, regions, and where possible, subregions;

(c) Assessment of associated benefits and costs of respective classes of banks in terms of ozone depleting potential and global warming potential;

(d) Exploration of the potential "perverse incentives" or other adverse environmental effects that may be associated with certain mitigation strategies, in particular related to recovery and recycling for reuse;

(f) Consideration of the positive and negative impacts of recovery and destruction of ozone-depleting substances, including direct and indirect climate effects;

(g) Consideration of the technical, economic and environmental implications of incentive mechanisms to promote the destruction of surplus ozone-depleting substances;

8. To request the Technology and Economic Assessment Panel to provide an interim report in time for dissemination one month before the twenty-ninth meeting of the Open-ended Working Group and to provide the final report one month before the Twenty First Meeting of the Parties to the Montreal Protocol;

9. To request the Ozone Secretariat, with the assistance of the Multilateral Fund Secretariat, to consult with experts from the United Nations Framework Convention on Climate Change, the Global Environment Facility, the Executive Board of the Clean Development Mechanism, the World Bank and other relevant funding experts to develop a report on possible funding opportunities for the management and destruction of ozone-depleting substance banks, to present the report to the Parties for review and comments one month prior to the twenty-ninth meeting of the Open-Ended Working Group and, if possible, to convene a single meeting among experts from the funding institutions;

10. That the report referred to in paragraph 9 of the present decision would focus on describing possible institutional arrangements, potential financial structures, likely logistical steps and the necessary legal framework for each of the following, if relevant:

(a) Recovery;

(b) Collection;

(c) Storage;

(d) Transport;

(e) Destruction;

(f) Supporting activities;

11. To request the Ozone Secretariat to convene a workshop among Parties that will include the participation of the Montreal Protocol assessment panels, the secretariat of the Multilateral Fund and the Fund's implementing agencies, and seek the participation of the secretariats of other relevant multilateral environmental agreements, non-governmental organizations and experts from funding institutions for the discussion of technical, financial and policy issues related to the management and destruction of ozone-depleting substance banks and their implications for climate change;

12. That the above workshop will be held preceding the twenty-ninth meeting of the Open-ended Working Group and that interpretation will be provided in the six official languages of the United Nations;

13. Further to consider, at the twenty-ninth meeting of the Open-ended Working Group, possible actions regarding the management and destruction of banks of ozone-depleting substances in the light of the report to be provided by the Technology and Economic Assessment Panel under paragraph 7 above, the working group report to be provided by the Secretariat under paragraph 9 above and the discussions emanating from the workshop under paragraph 11 above;

14. To request the Ozone Secretariat to communicate the present decision to the Secretariat of the United Nations Framework Convention on Climate Change and its Kyoto Protocol in time for possible consideration at the fourteenth meeting of the Conference of the Parties to the Convention and fourth meeting of the Conference of the Parties serving as the Meeting of the Parties to the Kyoto Protocol on the understanding that the decision is without prejudice to any discussions that may be held on ozone-depleting substance banks within their forum;

Annex 2 Biographies XX/7 Task Force members

Paul Ashford (UK)

Paul Ashford is the co-chair of the UNEP Rigid and Flexible Foams Technical Options Committee since 1998 and is the owner and managing director of Caleb Management Services Ltd., a consulting company working in the chemical regulatory and sustainability arenas. He co-chaired the End-of-Life Task Force in 2005, the TEAP Task Force on the Supplement Report to the IPCC/TEAP Special Report (2005), the Task Force on Emissions Discrepancies in 2006 and the 2007 Task Force on the Response to Decision XVIII/12. He has over 25 years direct experience of foam related technical issues and has conducted numerous studies to characterise the foam sector and inform future policy development. Much of his earlier work on banks, emissions and foam end-of-life management, performed to inform both IPCC and TEAP processes was supported by the US EPA. Non-TEAP work is covered under separate contracts from relevant commissioning organisations including international agencies (e.g. UNMFS, UNDP and UNEP DTIE), governments, industry associations and corporate clients. Mr. Ashford has no proprietary interest in alternatives or substitutes to ODS and does not own stock in companies producing ODS or alternatives or substitutes to ODS. A considerable portion of the work with private clients relates to the lifecycle assessment of products based on ODS alternatives and advice on carbon management strategies.

Julius Banks (USA)

Julius Banks is a full time environmental engineer at the Washington, DC Headquarters office of the U.S. Environmental Protection Agency (USEPA). Mr. Banks is the Team Leader for refrigerant recycling and emissions reduction programs. These programs include regulatory provisions for the maintenance, repair, and disposal of stationary refrigeration and air conditioning and motor vehicle air conditioning programs in the United States. Mr. Banks has regulatory experience dealing with ODS production and consumption programs, including the import of ozone-depleting substances for recycling or destruction. The USEPA has an interest in the topics of the Montreal Protocol because as a signatory to the Protocol the U.S. government has an interest in making certain that assistance is provided to Parties to the Protocol, specifically Article 5 signatories. Julius Banks has no proprietary interest in alternatives or substitutes to ODSs, does not own stock in companies producing ODS or alternatives or substitutes to ODSs, does not provide consulting services to organisations seeking to phase out ODSs. Julius Banks works as regulation writer at USEPA and occasionally consults on issues related to UN, UNEP, MLF, Implementing Agencies, governments, companies, etc. on matters related to the Montreal Protocol.

Christoph Becker (Germany)

Christoph Becker obtained a degree in environmental engineering from the University of Applied Science in Bingen (Germany) in 1985. After graduating, he worked for two years at the Saarland State Office of Environmental Protection (*Landesamt für Umweltschutz des Saarlandes*) and four years as a recycling manager at the municipality of Kaiserslautern. As a Manager for a German company specialising in fridge recycling he acquired the knowledge, experience and technical expertise for his work within the RAL Quality Assurance Association for the Demanufacture of Refrigeration Equipment – a registered association headquartered in Luxembourg. Since 1999 Christoph Becker holds the post of Secretary to the RAL Quality Assurance Association. The RAL Quality Assurance Association for the Demanufacture of Refrigeration Equipment, which operates under the umbrella of the RAL Institute, is an independent and – most importantly – a non-profit organisation. (www.ral-online.org). Becker as the head of the organisation has been invited by government ministries and agencies around the world to advise on fridge recycling and how high-quality, environmentally sound fridge recycling can be implemented. His work has influenced numerous national laws (e.g. in Denmark and the Czech Republic), regulations (e.g. in Austria) and official guidance (e.g. in the UK, Germany and Luxembourg).

Kristian Brüning (Finland)

Kristian Brüning is a founding executive of Climate Wedge Ltd Oy, an independent firm providing carbon finance and emissions trading related advisory and asset management services, and pursuing principal investments and project development in the carbon markets. Kristian Brüning has worked as a consultant in carbon- and emissions trading markets during the last 10 years through positions in corporate climate change strategy consulting, emission reduction project development and carbon fund advisory. In 2006 Kristian Brüning co-authored the first version of the Voluntary Carbon Standard and advised on the creation of a supporting voluntary carbon registry function. From 2007 onwards Kristian Brüning has worked on commercialising non-Kyoto greenhouse gases, such as NMVOCs and ODS, through voluntary carbon markets. In March 2008 Kristian Brüning co-wrote the article "Beyond the Kyoto Six" in Carbon Finance. During his career Kristian Brüning has worked with numerous global blue-chip industrial and financial sector clients on both compliance- and voluntary carbon-related issues. Prior to founding Climate Wedge Kristian was an assistant director at PricewaterhouseCooper’s climate change team in its energy corporate finance practice in London. Kristian holds an M.Sc (Intl. Econ) from Hanken in Helsinki and is an EFFAS certified financial analyst. Kristian Brüning has no proprietary interest in alternatives or substitutes to ODSs, does not own stock in companies producing ODS or alternatives or substitutes to ODSs. Kristian Brüning has a proprietary interest through Climate Wedge Oy and an indirect interest through advisory clients in developing the commercial prospect of utilising carbon markets for financing the cost of ODS destruction.

Michael Dunham (USA)

Michael Dunham is the Director of Energy & Environmental Programs for JACO Environmental, a US based company that specialises in appliance recycling for energy efficiency. JACO’s primary clients are major electric utility companies seeking to save electricity through offering customers the opportunity to turn in old, inefficient refrigerators for a cash incentive and lower monthly electric bills. JACO currently operates 17 facilities for over 60 utilities in the US and 1 in Canada that de-manufacture these appliances by separating over 95% of the materials used in the construction. During this process, all refrigerants and foam insulation materials containing CFC, HFC and HCFC are recovered and destroyed. JACO’s 2008 volumes exceeded 300,000 units and it expects to reach 500,000 units in 2009. Michael Dunham served on the 2004 TEAP Foams End-of-Life Task Force; he received the US EPA Stratospheric Ozone Protection Award in 2004 and a Best of the Best Award in 2007 at the 20th Anniversary of the Montreal Protocol. He has been certified by the RSES since 1992 for handling of refrigerants. JACO Environmental is a minority shareholder in EOS Climate, a US based company that was established to monetise carbon credits from the destruction of ODS with high GWP. EOS is also working on developing commercial applications for an ODS conversion technology invented by the University of Newcastle as an alternative to destruction.

Koichi Mizuno (Japan)

Dr. Koichi Mizuno, a member of the CTOC since 2005, is Research Advisor of the Research Institute of Environmental Management Technology at the National Institute of Advanced Industrial Science and Technology (AIST). He was a member of the Destruction Technology Sub Committee in 1991-1995, of the Task Force on Destruction Technologies in 2001-2003, and co-chair of the FTOC Task Force on Foam End-of-Life Issues in 2004-2005. He was also a Lead Author of the IPCC-TEAP Special Report in 2005. He invented two processes using inductively-coupled radio-frequency plasma and solid catalysis for destruction of fluorinated compounds such as CFCs, HCFCs, HFCs, and PFCs.

Lambert Kuijpers (The Netherlands)

Dr. Lambert Kuijpers is co-chair of the Technology and Economic Assessment Panel since 1992 and co-chair of the Refrigeration, Air-conditioning and Heat Pumps Technical Options Committee since 1989. He works on a part-time basis for the Department “Technology for Sustainable Development”, ECfS, at the Technical University Eindhoven, The Netherlands. He served on the Steering Committee to the “IPCC/TEAP Special Report in 2005, co-chaired the 2005 Task Force for the TEAP Supplementary Report, the 2006 Task Force on Emissions Discrepancies and the 2007 Task Force on the Response to Decision XVIII/12. He was a Lead Author for both the Third and the Fourth IPCC Assessment Report and was a member of the Ozone Science Assessment Panel in 2005-2006.

Until 1993, he worked for Philips Eindhoven (NL) in the development of refrigeration, air conditioning, and heat pump systems to use alternatives to ozone-depleting substances. Dr. Kuijpers has no proprietary interest in alternatives or substitutes to ODS and does not own stock in companies producing ODS or alternatives or substitutes to ODS. He occasionally is a consultant to governmental and non-governmental organisations, and is also an advisor to the Re/genT Company, Netherlands, which he co-founded in 1993 and where he still has a minority interest (this company is involved in the R&D of components and equipment for refrigeration, air-conditioning and heating).

Miguel Quintero (Colombia)

Prof. Miguel W. Quintero, Co-chair of the Foams Technical Options Committee since 2002, is a consultant in the area of polyurethane technology. He has been a professor at the Chemical Engineering Department at Universidad de los Andes in Bogota, Colombia, during 2000- 2006. Prof. Quintero worked during 21 years (until 2000) for Dow Chemical at the Research & Development Department in the area of rigid polyurethane foam. In the period January 2007- October 2008, he returned to Dow Europe as Development Leader for Polyurethane Product Research, located in Switzerland. He owns stock in companies that manufacture ozone-depleting substances and products made with or containing ozone depleting substances and their substitutes and alternatives. He is a regular consultant for the Montreal Protocol's implementing agencies.

Daniel Verdonik (USA)

Dr. Daniel P. Verdonik is co-chair of the Halons Technical Options Committee and member of UNEP's Technology and Economic Assessment Panel. He is the Director, Environmental Programs, Hughes Associates, Inc., in Baltimore, MD and Arlington, VA providing consulting services in fire protection and environmental management. Hughes Associates, Inc. has an interest in the topics of the Montreal Protocol because it provides a wide range of fire protection research, design and consulting services to government and corporate clients, including work related to halons and halon alternatives. Dr. Dan Verdonik has no proprietary interest in alternatives or substitutes to ODSs, does not own stock in companies producing ODSs or alternatives or substitutes to ODSs.

Trough Hughes Associates, Inc. Dr. Dan Verdonik provides consulting services for organisations seeking to phase-out ODSs. Dr. Dan Verdonik is a share holder in Hughes Associates, Inc., which does not own stock in companies producing ODSs, or alternatives or substitutes to ODSs. He currently provides consulting services through Hughes Associates, Inc, for the U.S. Army and U.S. Navy on matters related to the Montreal Protocol and has previously provided services through Hughes Associates Inc. for Implementing Agencies, U.S. EPA, U.S. Air Force and Chemtura (now DuPont).

Paulo Vodianitskaia (Brazil)

Paulo Vodianitskaia got a degree in mechanical engineering in Brazil (UFPr 1979). After a specialisation degree at the Université de Perpignan, France (1982), he got a Master Degree in Engineering in Brazil (UFPb) in 1984 with a thesis on solid adsorption, solar refrigeration. Paulo Vodianitskaia joined Whirlpool, a leading appliance industry, in 1985, where he was responsible for the R&D functioning and, for about eight years, he managed a group of researchers dedicated to technological innovation in electronics, artificial intelligence, heat and mass transfer, food science, and human comfort. He is EHS Regional Coordinator since 1998 and, as such, responsible for Sustainability Management at Whirlpool Latin America since 2004.

Paulo Vodianitskaia participated in many Montreal Protocol meetings as member of the Brazilian delegation, and also at the Rio+10 meeting in Johannesburg (2002) as a delegate of the Brazilian Industry Confederation. Between 2002 and 2007 he served in industry associations, as an environmental director for the Associação Brasileira da Indústria Eletro-Eletrônica - ABINEE, and thereafter as a co-ordinator for the

Technical and Environmental Working Group for the Associação Nacional dos Fabricantes de Produtos Eletro-Eletrônicos - ELETROS. He is author of a number of articles on subjects such as thermodynamics and energy efficiency. Since 1991 Paulo Vodianitskaia has served as a Lead Author in UNEP's Refrigeration Technical Options Committee an in several Task Forces established under the umbrella of UNEP, as well as in the IPCC TEAP 2005 Special Report.