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ODS and SGGs in Australia

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A study of end uses, emissions and opportunities for reclamation

For the Australian Department of Environment, Water, Heritage and the Arts

Prepared by
Energy Strategies
with Expert Air

environment

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ODS and SGGs in Australia – A study of End Uses, Emissions and Opportunities for Reclamation

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Preamble

This work represents the first attempt to quantify the ODS and SGG inventory in this way and has been compiled using the best data available. Any constructive feedback, referrals to other data sources, comments and observations from the industry or other interested parties would be welcomed.

Executive Summary

In 2006 approximately 4,890 metric tonnes of bulk synthetic greenhouse gases (SGGs) and ozone depleting substances (ODS)[1] were declared at point of import. These gases had an aggregate Greenhouse Warming Potential (GWP) equivalent to approximately 8.11 Mt of CO_2.

The total was comprised of:

- approximately 2,165 metric tonnes of HCFCs with a GWP of approximately 3.06 Mt CO_2-e; and,

- approximately 2,725 metric tonnes of HFCs with a GWP of approximately 5.06 Mt CO_2-e.

The declared bulk imports of HFCs are significantly lower, in GWP terms by some 16.4%, than the bulk HFC imports in 2005 of approximately 6.04 Mt CO_2-e.

These quantities above do not include ODS or SGGs declared when imported in pre-charged equipment. In 2006 approximately 2,300 metric tonnes of ODS and SGGs in equipment were declared at point of importation, which had an aggregate global warming potential equivalent to 3.54 Mt CO_2.

This was comprised of:

- approximately 756.4 metric tonnes of HCFCs with a GWP of approximately 1.12 Mt CO_2-e; and,

- approximately 1,544.4 metric tonnes of HFCs with a GWP of approximately 2.42 Mt CO_2-e.

The imports of SGGs in pre-charged equipment represents an increase of more than 64% on the approximately 1.48 Mt CO_2-e of SGG imports reported in 2005.

As a result, this study concludes that the sum of bulk imports of ODS and SGGs, plus ODS and SGGs declared in pre-charged equipment in 2006, were approximately 7,191 metric tonnes with a GWP equivalent to approximately 11.64 Mt of CO_2.

This total was comprised of:

- 2,921.4 metric tonnes of HCFCs with an equivalent GWP of approximately 4.18 Mt of CO_2; and

- 4,269.4 metric tonnes of HFCs with an equivalent GWP of approximately 7.48 Mt of CO_2.

[1] Gases referred to as synthetic greenhouse gases – SGGs – in this report are gases reported to the National Greenhouse Gas Inventory and subject to controls under the Kyoto Protocol. In this report SGGs referred to are primarily hydrofluorocarbons or HFCs, though may also include perfluorocarbons or PFCs where stated. Gases referred to as ozone depleting substances – ODS – in this report are gases subject to controls under the Montreal Protocol. In this report this is primarily hydrochlorofluorocarbons, or HCFCs. As well as being ozone depleting substances HCFCs also have a global warming effect and thus a global warming potential value. ODS can also refer to chloroflourocarbons, or CFCs, the most common refrigerant gas in the 1980s and the one with the highest ozone depleting potential that spurred the world to create the Montreal Protocol and embark on a global transition away from CFCs.

More than 37% of bulk imports were HCFCs, the balance being HFCs. Approximately 33% of gas imported in pre-charged equipment were HCFCs, the balance being HFCs.

A quantity of ODS and SGGs that was re-exported was identified equivalent to approximately 254 kt of CO_2.

There is presently not enough information to be able to conclude how much of the decrease in imports of bulk HFCs between 2005 and 2006 might be attributable to annual variability in imports, or may be as a result of a shift to more equipment being imported pre-charged, as opposed to being manufactured, or at least fully charged at commissioning in Australia.

A great deal of work was undertaken to estimate the bank of working ODS and SGGs in Australia, building on previous studies into the stock of equipment in Australia and the bank of HCFCs. The study calculated that the working bank of ODS and SGGs in Australia in 2006 was approximately 30,574 metric tonnes with an aggregate GWP equivalent to approximately 49.7 Mt of CO_2. The bank is approximately 56% HCFCs and 44% HFCs.

While there is some uncertainty about the most appropriate leak rates to apply to calculations of losses from various classes of equipment, it was calculated that the bank of working gas is incurring losses to atmosphere of approximately 2,658.2 metric tonnes per annum with a GWP equivalent to 4.473 Mt CO_2. This is an amount equal to more than 56% of all bulk ODS and SGG gas imports into Australia in 2006. It is estimated that leaks were comprised of:

- Approximately 1,247 metric tonnes of HCFCs with a GWP equivalent to 1.86 Mt of CO_2; and,
- Approximately 1,412 metric tonnes of HFCs with a GWP equivalent to 2.71 Mt of CO_2.

A further approximately 1,053 metric tonnes of ODS and SGGs are contained in equipment reaching the end of its useful life. This end-of-life gas has an aggregate GWP of approximately 1,503 kt CO_2-e.

Thus the total ODS and SGG estimated to be leaking from the working bank of gas, plus the estimated losses from end-of-life equipment, totalled 3,711 metric tonnes in 2006 with an aggregate GWP of 6.08 Mt CO_2-e.

End-of-life opportunities were modelled with potential recovery percentages ranging from 50% for domestic air conditioning/commercial refrigeration to 60% for automotive and 80% for domestic refrigerators, yielding a potential end-of-life gas recovery opportunity with an aggregate GWP of 1,556 kt CO_2-e.

Chapter 6, which details projections of future demand for HCFCs, is an extract from an earlier work – '*HCFCs in Australia – Projections of Future Demand*' (August 2007). This research indicated that the growing bank of HCFC charged equipment would be likely to require quantities of gas for servicing that could be greater than the declining Australian cap on imports of ODS from as soon as 2010.

At this time, while there is a declining cap on imports of HCFCs, there is no restriction on the import of HCFC pre-charged equipment. Predictions made by researchers in the early years of this decade, regarding the rates of transition from HCFC charged equipment to HFCs, have not eventuated. As a result, there has been a very significant increase in the stock of HCFC equipment in Australia. This trend is still continuing, even while the availability of bulk HCFCs has been declining.

At the time that work was done, no attempt was made to model the potential HCFC service demand that might be met as a result of increased end-of-life recoveries of ODS in Australia or any other gas reclamation and recycling potential.

1. Background, Sources and Methodology

The Commonwealth Department of the Environment, Water, Heritage and the Arts (DEWHA), commissioned Energy Strategies to complete "*A report on Australia's current usage of bulk ODSs/SGGs and of products containing these substances*" and, further, to conduct a "*Survey of refrigerant recovery*", and to develop '*Estimates of refrigerant banks, emissions and potential recovery.*"

Energy Strategies, in association with Expert Air, had previously completed three significant pieces of research[2] in this sector during 2007, '*Cold Hard Facts*', '*The HCFC Bank in Australia*' and '*HCFCs In Australia – Projections of Future Demand*', all of which were used as starting points for this work. Along with these three larger research tasks, Energy Strategies had completed a number of smaller and associated tasks in this sector including;

- devising a long term strategy to improve the energy efficiency of heating, ventilation, air-conditioning and refrigeration (HVAC&R) equipment in non-residential buildings;
- participated in developing a strategy for improving the energy efficiency of residential air-conditioning systems;
- provided analysis on the trends in the residential and small commercial air-conditioning, water and space heating market in Australia; and
- participated in a number of air-conditioning planning forums and conferences.

While these latter activities were valuable in expanding Energy Strategies' understanding of and access to the HVAC&R industries, it was the three major reports listed above that provided the basis of the data used in this study.

1.1. Data Sources

'*Cold Hard Facts*' was a first attempt at mapping and quantifying the entire HVAC&R sector. This study encompassed a broad sweep of economic activity and classes of technology for which the simple and common linking factor is the use of a compressor to transfer heat with a working gas.

Using this technological definition of the area of interest, '*Cold Hard Facts*' required 6 months of research to compile data on every significant refrigeration and air-conditioning application including across:

- the cold chain;
- commercial and industrial refrigeration and chilling;
- residential and retail refrigeration and cool rooms;
- residential and commercial air-conditioning; and
- transport refrigeration and mobile air-conditioning.

[2] 'Cold Hard Facts – The Refrigeration and Airconditioning Industry in Australia' in June 2007, and 'An Assessment of the HCFC Bank in Australia and Forecasts of Future Demand," August 2007.

This major work drew on all available previously published sources of data on any of these areas, used segment specific market research reports, checked annual reports and public statements of some of the major market participants, and went directly to companies involved in manufacturing, distribution, sales and installations of equipment and components, to verify data. The end result is a snapshot of the installed base of most types of equipment in 2006.

It was not a completely comprehensive final report, as meaningful data simply was not discovered or developed for some of the more specialised applications at that time in areas such as process chilling in industrial applications like plastics moulding, and in marine and aviation end uses. However for the major application areas it provides a reasonable measure of the majority of the compressor driven equipment working in the economy at that time.

'*The HCFC Bank in Australia*' built on the '*Cold Hard Facts*' database, and used the equipment populations from that study to underpin estimates of the bank of working gas. The '*HCFC Bank*' study also had access to some very good primary data in the form of bulk gas and pre-charged equipment import data, collected by DEWHA. The '*HCFC Bank*' study was then used as the basis of estimated future demand for HCFCs.

1.2. Methodology

The starting points for preparing an inventory of end uses, estimating emissions and assessing opportunities for reclamation were the:

- Import data of bulk gases and pre-charged equipment;
- Extensive interviews about end uses and users, industry practices and equipment performance with:
    - importers of bulk gases and pre-charged equipment;
    - distributors of gases and components;
    - end users of bulk gases;
    - installers of equipment, service companies, technicians and reclamation specialists; and
    - industry associations.
- The estimates of the stock of equipment from '*Cold Hard Facts*';
- Estimates of emission, loss and leak rates from equipment at installation, during operation, when being serviced and maintained and when being removed and disposed of.

The scale of the various end uses, in terms of the bank of working gas and the metric tonnes of gases consumed per annum, was derived from this research. In the end, more than 60 extensive interviews were conducted with expert informants and industry participants to verify data and assumptions, including service volumes and maintenance characteristics of particular classes of equipment. Every interview resulted in a number of subsequent emails and phone calls resulting in hundreds of inputs from every sector of the industry.

Emissions from HVAC&R equipment and emissions from other manufacturing uses and products were calculated separately.

The task of establishing emissions from HVAC&R equipment required an estimate of the split across the bank of working gases of the main species of gases. By analysing the gas species used in pre-charged imports and through checking manufacturers' specifications, the split between HFCs and HCFCs in the bank of working gases was estimated for each major category of equipment.

The volume of bulk gas consumed in manufacturing of HVAC&R equipment in Australia is well known from annual reports, Australian Bureau of Statistics data and interviews with the relatively small number of manufacturers of vehicles and equipment in Australia. The volume of bulk gas consumed when commissioning new installations of equipment has been estimated from direct experience in the field of a range of stationary applications and through interviews with importers, manufacturers, service companies, engineers and technicians. It was then assumed that the balance of imported bulk gas, that was not being used in a manufacturing process or at commissioning in new installations, was being used in servicing equipment.

The results of these calculations were then verified through further extensive interviews with bulk gas importers, equipment retailers and installers, service companies and other stakeholders. This 'top down' approach arrived at a reasonable reconciliation of all end uses of bulk imports for 2006.

A second approach to the issue of emissions was to work out the losses from the stock of equipment by applying average leak rates of equipment to average charges of gas used in each equipment category and class within that category. This was assisted by having quite high resolution data on the various sizes of equipment in the market from sales data, and import data on pre-charged equipment that specified a range of gas charges.

The issue of leak rates is possibly the most contentious set of assumptions in the entire process. Accepted leak rates is an issue about which there is significant uncertainty, as what can appear to be quite small differences in the estimated loss of gas at installation, or over the life of a piece of equipment, can lead to vastly different outcomes for estimates of total emissions or future demand when those leak rates are aggregated over large stocks of equipment, and service life that can extend to two decades.

Different leak rates for similar equipment types are reported in studies by the European Commission Report (2006)[3], US EPA Report (2006)[4], UNEP Technical Options Committee (2006)[5] and by the International Panel on Climate Change (IPCC, 2005)[6] (used in AGO Factors and Methods Workbook, 2006).

The reality is that the same type of equipment can exhibit different leak rates when operating on different refrigerants (due to different operating pressures) and in different applications (with resulting variations in duty and maintenance). Equipment designed and used for the same applications, ie lumped into the same categories, but from different vintages, will have different leak rates (ie new supermarket versus old supermarket equipment). While taking the international published data into account, the authors conferred widely with practitioners in the field who

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[3] '*Supply and Demand of Recycled Hydrochlorofluorocarbons (HCFCs) in Existing Refrigeration and Air-Conditioning Equipment Beyond 2009: Analysis of Regulatory Phaseout Scenarios*' European Commission, August 2006, Fig. 6, pg 7

[4] '*The US Phaseout of HCFCs: Projected Servicing Needs in the US Air-Conditioning and Refrigeration Sector*', ICF International for US EPA, Sept, 2006, Table A-1, pg 31

[5] UNEP, *2006 'Report of the Refrigeration, Air-Conditioning and Heat Pumps Technical Options Committee*', pg 1.

[6] IPCC, 2005 '*Safeguarding the ozone layer and global climate system*'

installed and serviced equipment to develop a set of leak rates from different categories of equipment in Australian conditions.

Having settled on average leak rates that could be applied, the calculation of losses from the estimated stock of equipment actually tallied quite closely with the top down approach that derived an estimate of bulk gas being consumed in servicing equipment.

As well as improving our understanding of uses of ODSs/SGGs in the ‘mainstream’ applications of HVAC&R, and in areas such as refrigerated transport, off-road vehicles and maritime applications, this study was required to investigate industry sectors and applications outside of the HVAC&R sector, including foam manufacture, medical and industrial aerosols and solvents, fire protection and electronics.

The difference between estimates of service demand for gas for HVAC&R equipment, as verified by calculation of installation losses and leak rates, and the total of all bulk gases imported, was accounted for in these other uses such as in foam manufacture, use as a fire suppressant, or in specialised applications. Most of the data for these other uses was derived by interviews with industry participants as there was scant published data except for some slightly better informed estimates in foam production.

Nomenclature

Throughout this report references to ODS can be taken to mean hydrochlorofluorocarbons or HCFCs. These gases are subject to international agreements under the *Montreal Protocol on Substances that Deplete the Ozone Layer*. References to SGGs can be taken to mean hydrofluorocarbons, or HFCs. References to SGGs may also refer to perfluorocarbons where specifically mentioned. Both types of gases, ODS and SGGs, have global warming impacts and the global warming potential, or GWP, of volumes of gases is often referred to throughout this report.

The GWP values used to calculate the total impact of any volume of an ODS or SGG are generally those values used internationally and published by the IPCC in 1996. These are the same values used by the National Greenhouse Gas Inventory in Australia. Where gases are not listed by the IPCC because they are not subject to reporting under the United Nations Framework Convention on Climate Change, then values published by the World Meteorological Organisation are used.

2. ODS and SGG Imports and Trends in Australia

2.1. ODS and SGG imports

A total of approximately 7,191 metric tonnes of ODS and SGGs, which had an aggregate GWP equivalent to approximately 11.64 Mt of CO_2, were imported as bulk gas, or in pre-charged equipment into Australia in 2006.

Table 1. Declared ODS and SGG imports in 2006 (in metric tonnes and CO_2-e).

HCFCs	Tonnes	kt CO_2-e	HFC	Tonnes	kt CO_2-e
HCFC-123	17.52	1.58	HFC-134a	1712.67	2226.47
	0.51	0.05		587.66	763.95
HCFC-124	1.91	0.9	*HFC Blends*		
			HFC 407A		
HCFC-141b	241.29	172.04		3.75	6.63
			HFC blends		
HCFC blend 141b/22	17.04	28.63		0.83	1.73
	46.42	51.09	**Total Blends**	**4.58**	**8.36**
HCFC-142b	17.69	31.83	*HFC Secondary*		
			HFC 410A	127.39	219.74
HCFC-22	1794.02	2691.03		795.74	1372.66
	709.46	1064.19	HFC 407C	84.45	71.74
HCFC-225ca	0.26	0.03		136.22	207.88
			HFC 404A	698.84	2241.89
HCFC-225cb	0.34	0.2		20.07	65.43
			HFC 125		
HCFC-406A	7.83	9.4		0.09	0.26
			HFC-Mix	101.98	287.87
HCFC-408A	13.68	38.31			
			Total HFC Secondary	**1964.78**	**4467.47**
HCFC-409A	53.9	80.85	**HFC-Exotic**		**8.63**
	0.01	0.02			
HCFC Total	**2921.88**	**4170.15**	**HFC Total**	**4269.69**	**7474.88**
Bulk Imports	Pre-Charged Equipment		**Bulk Imports**	**4890.81**	**8111.14**
			Pre-charged Equipment	**2300.76**	**3533.89**
			TOTAL	**TONNES**	**kt CO_2-e**
				7191.57	**11645.03**

The largest use of imported ODS and SGGs in 2006 was in refrigeration applications, followed by stationary air-conditioning applications.

All refrigeration applications, both stationary and transport, consumed some 40% of all bulk gas imports, air-conditioning applications consumed approximately 31% of all bulk imports and mobile air-conditioning consumed a further 21% of all bulk gas imports.

Table 2. ODS and SGG end uses by industry sector in 2006 (in metric tonnes)

Industry Sector	HCFC Bulk Imports	HCFCs Precharged Equipment	HFCs Bulk Imports	HFCs Precharged Equipment	ODS and SGG End Uses – All Species
Refrigeration					
Transport Refrig	133.20		94.61	10.73	238.54
Commercial Refrig	361.67	1.76	778.29	40.63	1182.35
Domestic Frig and Freezer		2.28	77.17	104.24	183.69
Total Refrig	***494.87***	***4.04***	***950.07***	***155.60***	***1604.58***
Air-conditioning					
Chillers and other Commercial	260.97	25.43	203.28	75.22	564.90
Portable AC	0.29	607.59	1.00	850.33	1459.21
Split Systems	958.79	112.83	132.29	34.62	1238.53
Packaged Systems	153.67	6.50	18.74	37.99	216.90
Total AC	***1373.71***	***752.35***	***355.31***	***998.16***	***3479.53***
Mobile AC					
Passenger Vehicles			1165.63	353.59	1519.22
Other - off road etc	7.83		112.33	37.02	157.18
Total Mobile AC	***7.83***		***1277.96***	***390.61***	***1676.40***
Other					
Foam	258.49		33.74		292.23
Specialised and Aerosol			22.90		22.90
Solvents	30.60				30.60
Fire Suppression			85.35		85.35
Total Other	***289.09***		***141.99***		***431.08***
TOTAL	***2,165.50***	***756.39***	***2,725.33***	***1,544.35***	***7,191.57***

Table 3. ODS and SGG end uses by industry sector in 2006 (in kt CO_2-e)

Industry Sector	HCFCs Bulk Imports	HCFC Precharged Equipment	HFCs Bulk Imports	HFCs Precharged Equipment	ODS and SGG End Uses All Species
Refrigeration					
Transport refrigeration	201.40		305.10	13.00	506.50
Commercial refrigeration	542.20	3.00	2091.20	85.00	2633.40
Domestic refrigeration and freezers		5.00	104.50	144.00	104.50
Total Refrigeration	***743.60***	***8.00***	***2500.80***	***242.00***	***3494.40***
Stationary air-conditioning					
Chillers	367.50	37.00	233.70	100.00	601.20
Split systems	0.40	892.00	1.00	1451.00	1.50
Packaged systems	1449.80	169.00	232.00	57.00	1681.80
Small portable air-conditioning	232.40		21.90	71.00	254.20
Total Stationary Air-conditioning	***2050.10***	***1098.00***	***488.60***	***1669.00***	***5305.70***
Mobile air-conditioning					
Cars			1578.00	460.00	1578.00
Trucks	9.40		149.30	48.00	158.60
Total Mobile Air-conditioning	***9.40***		***1727.30***	***507.00***	***2243.70***
Other					
Foam	229.90		75.90		305.80
Specialised and Aerosol			39.60		39.60
Solvents	21.60				21.60
Fire Suppression			224.30		224.30
Total Other	***251.50***		***339.80***		***591.30***
Grand Total kt CO_2-e	***3,054.6***	***1,116***	***5,056.5***	***2,419***	***11,635.10***

In 2006 approximately 2,300 metric tonnes of ODS and SGGs in equipment were declared at point of importation, which had an aggregate global warming potential equivalent to 3.53 Mt CO_2.

This was comprised of:

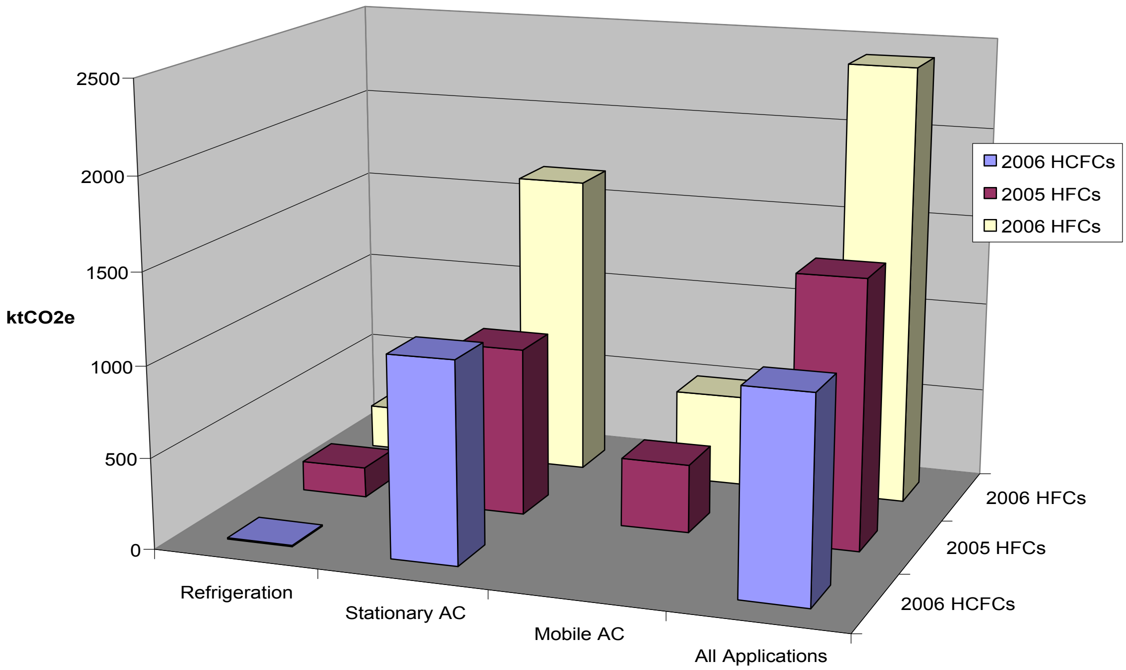
- approximately 756.4 metric tonnes of HCFCs with a GWP of approximately 1.11 Mt CO_2-e; and,
- approximately 1,544.4 metric tonnes of HFCs with a GWP of approximately 2.42 Mt CO_2-e.

The imported HFCs in pre-charged equipment in 2006 represented a very substantial increase of nearly 64% on the approximately 1.48 Mt CO_2-e of HFC imports reported in pre-charged equipment in 2005.

This means an additional approximately 943 kt CO_2-e worth of HFCs entered the country in pre-charged equipment in 2006, a number that is co-incidentally very similar to the 988 kt CO_2-e reduction in bulk HFC imports observed between 2005 and 2006.

Figure 1 illustrates the significant growth in HFC pre-charged equipment for the two years that data is available.

Figure 1: Precharged Equipment Australia 2006 and HFC Precharged 2005 ktCO$_2$e



Although growth in imports was observed across nearly all categories, the most significant area of growth in pre-charged imports was in stationary air-conditioning, and not just in smaller domestic devices, but also in chillers and other commercial systems.

However it is too simplistic to attribute any direct relationship between the growth of pre-charged imports and the apparent drop in bulk imports and conclude that this represents a decline in Australian manufacturing of air-conditioning equipment. This is underlined by the fact that increases in HFC pre-charged equipment was seen across all categories, and notably in several where there is little or no Australian manufacturing activity such as in split systems and chillers.

One notable trend that has some impact on these values has been a decline in the practice of charging larger chiller systems after import into Australia. This equipment was previously arriving from overseas without any gas charge and then being charged upon commissioning. This practice has declined recently with more large equipment now arriving pre-charged.

In commercial refrigeration, Australia does have an active domestic manufacturing base and, although imports apparently rose in this area, there is no reliable data available to conclude that this observed increase was all at the expense of domestically manufactured units, although there is some anecdotal suggestion that this is at least partly the case.

In the area of packaged systems (or roof top systems), where Australia has significant and competitive manufacturing capacity, there was an observed decline in imports.

Continued strong growth of imports of pre-charged split systems, most commonly used in larger homes and in small commercial applications, is an extension of a trend that has previously been observed and underway for several years.

Approximately 33% of the working gases declared in pre-charged imports were HCFCs, the balance being HFCs.

2.2. ODS and SGG exports

While compiling the inventory some small but significant export activities were identified. While there is a high level of uncertainty in regard to some of the values derived from the data discovered, or data provided on export volumes, an attempt has been made to quantify exports by application. As set out in Table 4, approximately 168 metric tonnes of ODS and SGGs are exported in equipment, or after servicing equipment on shipping. This material has an aggregate GWP equivalent to approximately 283 kt of CO_2.

Table 4. Estimates of ODS and SGG Exports from Australia

	Tonnes	kt CO_2-e
Passenger MAC: HFC 134a	78	101.4
Domestic refrigeration and freezers: HFC 134a	10	13
Commercial refrigeration: HFC 134a	5	6.5
Shipping Industry: HFC 404A	26	84.76
Shipping Industry: HCFC 22	39	58.5
Refrigerant Re-exported: HFC 404A	2	6.52
Refrigerant Re-exported: HCFC 22	8	12
	168	***282.7***

The largest single export volume is material exported in mobile air-conditioning systems in vehicles. Confidence in this number is high, being about 78 metric tonnes of HFC 134a, equivalent to about 101 kt CO_2. Similarly the export of 10 metric tonnes of HFC 134a in domestic appliances is also highly certain, being equivalent to approximately 13 kt of CO_2.

Certainty in the balance of estimated exports of approximately 80 metric tonnes of various ODS and SGGs is low. Shipping industry exports for instance could potentially be more than 50% greater than estimated here as the information gathered so far is based on interviews with only some of the parties involved in servicing shipping visiting Australian ports.

However conservative estimates have been made regarding shipping and other exports so that there is little doubt that *at least* the 168 metric tonnes of material is exported, equivalent to approximately 3.4% of all bulk imports in 2006.

3. End Uses of ODS and SGG Imports in Australia

Table 5 lists all of the common applications for ODS and SGGs in Australia.

Table 5. Applications of ODS and SGGs in Australia

Industry Sector	HCFCs	HFCs	PFCs	SF_6
Air Conditioning Equipment				
Stationary: Residential & LC	✓	✓		
Stationary: Commercial	✓	✓		
Mobile: Motor Vehicle AC		✓		
Other Mobile AC	✓	✓		
Refrigeration				
Domestic		✓		
Commercial Refrigeration	✓	✓		
Industrial Process Refrigeration				
Cold Storage	✓	✓		
Refrigerated Transport		✓		
Fire Suppression		✓	✓	✓
Foam Blowing	✓	✓		
Aerosols (MDIs)		✓	✓	
Solvent Cleaning	✓	✓	✓	
Computer Dusters				
Non-Montreal Protocol Industries				
Metal Processing				✓
Switchgear & Circuit Breakers				✓
Electronics/Semi Conductors		✓	✓	✓
Aluminium Production			✓	
Magnesium Die Casting				✓
Other				
Fingerprint Detection		✓		
Heat Transfer Fluids			✓	
Paper Deacidification		✓	✓	
Sports Gear				✓
Radar Equipment & Night Vision Goggles				✓
Laboratory Uses	✓	✓	✓	✓

Some of these applications, while certainly common practice in their industries, such as the use of HFCs to de-acidify works on paper by materials conservationists or the use of HFCs as a solvent in fingerprint detection, consume such small quantities that they barely rate mention.

As one would expect, most gas is used as a heat transfer medium in refrigerating, air-conditioning and chilling applications. Foam blowing agents and fire suppression agents are an order of magnitude smaller than the RAC applications.

Table 6. End uses of main bulk imported species of ODS and SGG, 2006 (in kt CO_2-e)

	All Species	HCFC 22	HCFC 141b	HCFC 408A	HCFC 409A	HFC 134a	HFC+ Secondary
Refrigeration							
Transport refrigeration	506.50	201.40				7.60	297.50
Commercial refrigeration	2,633.40	447.30		38.30	56.60	140.50	1,950.70
Domestic refrigeration and freezers	104.50					104.50	
Total Refrigeration	*3,244.40*						
Stationary air-conditioning							
Chillers & other commercial	601.20	340.80			24.30	181.30	52.40
Refrigerated portable	1.50	0.40				0.40	0.60
Split systems	1,681.80	1,449.80				12.90	219.10
Packaged systems	254.20	232.40				7.20	14.70
Total Stationary Air-conditioning	*2,538.70*						
Mobile air-conditioning							
Passenger	1,578.00					1,578.00	
Other(Trucks/ Train/ Defence/ Marine/Off-Road)	158.60					144.50	4.80
Total Mobile Air-conditioning	*1,736.60*						
Foam	*305.6**	*18.90*	*150.60*				*57.30*
Aerosols & Specialized Applications	*39.60*					*31.00*	
Solvents	*21.40*		*21.40*				
Fire equipment	*224.30*						*224.30*
Total kt CO_2-e	***8,111^***	***2691***	***172***	***38.3***	***80.8#***	***2226.47***	***2821.1***

Numbers may not add due to rounding.

* The balance of foam blowing agents are HCFC Blend 141b/22 (28.6 kt CO_2-e), HCFC 142 (31.8 kt CO_2-e).

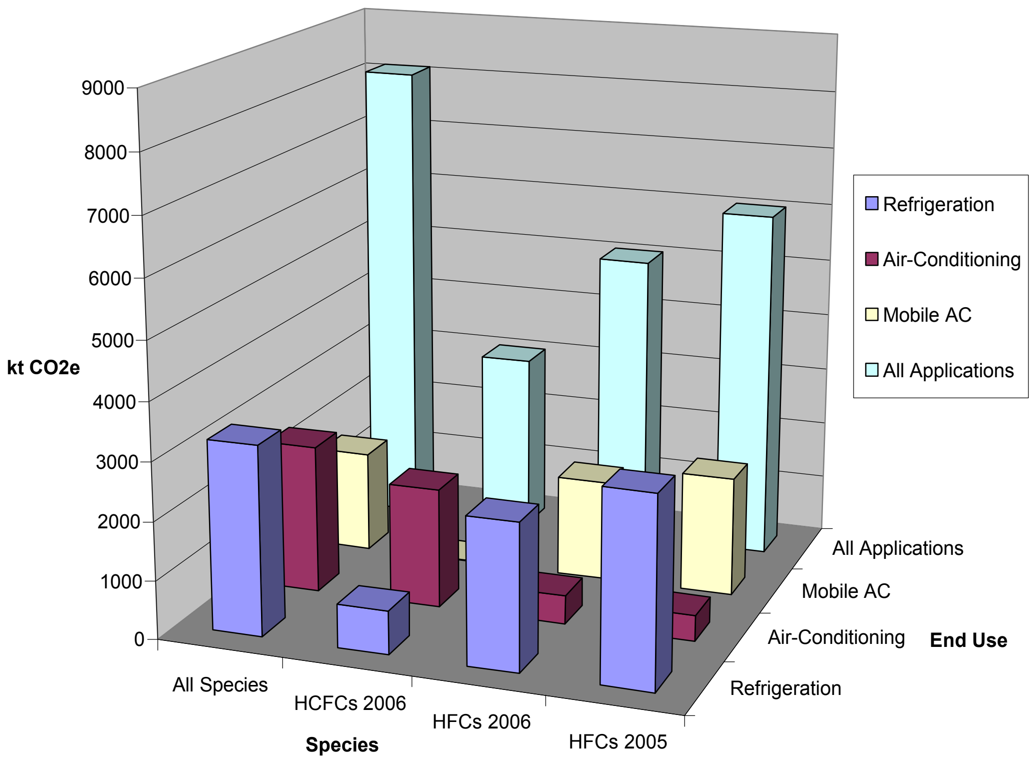
+ HFC Secondarys are used to produce HFC blends such as R404A, R407A and C, R410Aand include HFC-32, HCF-125, HFC-143a, HFC-152a, HFC-218. These blends often include a proportion of HFC-134a.

^ A total of 81.3 kt CO_2-e included in the total but not shown in under individual species include the 60.4 kt CO_2-e of HCFC Blend and HCFC 142 foam blowing agents mentioned above plus 1.6 kt CO_2-e of HCFC-123 used in chillers and other commercial, 0.9 kt CO_2-e HCFC 124 used in chillers and other commercial, 0.03 kt CO_2-e HCFC-225ca thought to be used in solvents, 0.2 kt CO_2-e HCFC-225cb thought to be used in solvents, 9.4 kt CO_2-e HCFC-406A used to replace CFCs in some large and off-road mobile air-conditioning, and 8.6 kt CO_2-e Exotic HFCs thought to be used in specialised applications and possibly some aerosols.

Table 6 lists the end uses of the major species imported in bulk and the GWP of the volumes calculated as being consumed in each application area in 2006. This table shows that refrigeration and stationary air-conditioning consumed more than 71% of all bulk ODS and SGGs imported into Australia in 2006. Mobile air-conditioning systems consumed another 21% and the balance of less than 8% was used across all other uses including foam blowing agents, in fire suppression, as solvents and in various industrial and chemical applications.

Figure 2 further illustrates the predominance of the various refrigeration and air-conditioning applications as the primary end uses of the majority of all imported gases.

Figure 2: Major End Uses of Bulk ODS and SGG Imports Australia 2006 kt CO2e



3.1. Refrigeration

This sector covers all applications of refrigeration. This encompasses an enormous range of equipment ranging from the smallest domestic refrigerators and freezers to commercial refrigeration equipment, a very wide group that includes:

- 'self-contained' glass fronted drinks fridges visible at every corner store, takeaway shop and petrol station;
- the sometimes elaborate and extensive deli and food display cabinets found in sandwich bars, cafes and restaurants; and
- the sometimes enormous open front, open top or glass fronted frozen and chilled goods displays in very large supermarkets.

Approximately 40%, in GWP terms, of all bulk ODS and SGG imports into Australia in 2006 were used in refrigeration. This is made up of approximately 1,317 metric tonnes of ODS and SGGs with a GWP of approximately 3.24 Mt CO_2-e.

More than three quarters of that amount (equivalent to 1,054 metric tonnes or 21% of total bulk imports) was consumed in commercial refrigeration, most of which was used in the servicing and maintenance of existing equipment. This class of equipment, the large shop and supermarket refrigerators, are very energy intensive and very hard working, designed as they are to maintain quite closely controlled conditions in situations where doors are constantly opened. Open front and open top displays are simply exposed to numerous sources of radiated or convective heat.

Large refrigeration plants operating in Australia's approximately 3,600 supermarkets, some with a single gas charge of as much as 900 kg, consumed a total of 356 metric tonnes of ODS and SGGs in 2006. Of this material an estimated 285 metric tonnes was used to replace material lost to leaks. Much of this replacement gas was HFC 404A (237 metric tonnes) with an additional 47 metric tonnes of HCFC 22 also used.

Approximately 71 metric tonnes of the total 356 tonnes used in this class of technology was consumed by manufacturers constructing these systems. All of this original equipment manufacturer (OEM) consumption was HFC 404A.

Commercial refrigeration systems, the sort of equipment that operates in hotels, delis , takeaway food stores and also in dairies, are estimated to have consumed approximately 520 metric tonnes of ODS and SGGs in 2006, of which 333 tonnes was to top up gas lost to leaks. This gas was used across an estimated 330,000 bits of equipment.

An estimated 96 metric tonnes of ODS and SGGs were used in commercial equipment employed in the retail food industry, some 91 tonnes in pubs, clubs and hotels, and more than 83 tonnes in the dairy industry with smaller quantities in cool rooms, in catering and hospitality and in self-contained and small commercial refrigeration.

In terms of the various gas species, the servicing requirements of this commercial equipment consumed some 99 metric tonnes of HCFC 22, an estimated 124 tonnes of HFC 404A, 69 tonnes of HFC 134a and 31 tonnes of HCFC blends.

Approximately 187 metric tonnes of gas, out of the 520 tonnes used in commercial refrigeration equipment in 2006, was estimated to have been used in the domestic manufacture of commercial refrigeration equipment. In this sector a quite active, innovative set of manufacturers fabricate a very wide range of standard commercial equipment stock, plus all manner of customized and once-off pieces for specialist uses. The OEM consumption in 2006 was almost entirely HFCs (109 tonnes HFC 404A and 71 tonnes HFC 134a) with only an estimated 6 tonnes of HCFC 22 being consumed by OEMs. Industry sources suggest that by the end of 2008 there will be no more use of HCFC 22 by OEMs.

The 'cold chain', the nationwide system of large chilled storage facilities through which the food distribution system operates, and which is largely serviced by large chiller systems, is estimated to have used 178 metric tonnes of gas in 2006 of which approximately 109 tonnes was used to service the more than 11,800 devices. Some 69 tonnes is estimated to have been used in charging new equipment, most of which would have been imported without a gas charge. This new equipment in this class consumed some 25 tonnes of HCFCs, an estimated 34 tonnes of HFC 404A and a further 9 tonnes of HFC 134a

Because a large number of these long lasting machines are still charged with HCFC 22, a large proportion of the service consumption was HCFC 22 (72 tonnes), the balance being HCFC blends (8 tonnes), HFC 404A (25 tonnes) or HFC 134a (4 tonnes).

Outside of the 'cold chain' capacity dedicated to food distribution, there is another large cool storage capacity, mostly at ports around the country, through which export and import food stuffs are moved but also other materials that must be kept temperature controlled or frozen including pharmaceuticals and medical supplies, blood plasma products, veterinary drugs and materials and agricultural products such as seed stocks, etc.

This cold storage space is estimated as comprising some 9,460,000 square metres of space. However a very large and increasing proportion of the very large chiller and cascading refrigeration systems that control the temperature in this sector is now running on ammonia. More of this capacity is moving to ammonia every year. As such the total use of ODS and SGGs in this sector was thought to be only 21 metric tonnes of HCFC 22 in 2006, with no new facilities being commissioned in that year that used any ODS or SGG.

Some 179 metric tonnes of ODS and SGG were used in transport refrigeration, almost all of which (~156 tonnes) was used to service existing equipment to replace lost gas. A large proportion of the service consumption, estimated to be more than 104 tonnes, was HCFC 22. A further approximately 35 metric tonnes of HFC 404A and some 16 tonnes of HCFC blends were also used in the service of refrigerated transport. An estimated 22 metric tonnes of ODS and SGG were used by OEMs in this class of equipment in 2006 with the majority of it (~19 tonnes) being HFC 404A.

An estimated 84 metric tonnes of HFC 134a was used in the manufacture of an estimated 550,000 domestic refrigerators and freezers in 2006, some 10 tonnes of which was then exported in possibly 68,000 refrigerators and freezers to overseas markets.

There is little comparative data to predict trends across this sector other than to note a continuing decline in the use of HCFCs. Earlier studies noted that some of the largest plant installed in the cold chain, at ports and in the big food distribution centres have been refitted with ammonia in the last few years. This is primarily because large ammonia systems are more energy efficient than plant running on ODS or SGGs and the equipment lasts longer as the compressors have to do less work. The on-site engineering capabilities at the largest plants means it is easier to run an ammonia system safely.

Early trials in moving some supermarket scale systems to CO_2 are underway. However, this is not yet a widely accepted practice and the skilled engineering to do this on a large scale is not yet in place. Some drink vending machines are reportedly starting to be manufactured fitted for CO_2.

Significant changes are forecast in volumes of gas consumed by domestic appliance manufactures. Domestic refrigerators and freezers manufactured by Fisher and Paykel and Electrolux all use HFC 134a. While this activity was likely to have been essentially stable for 2007, in future years there will be less manufacturing of domestic appliances in Australia, with Fisher and Paykel announcing in April 2008 the closure of their main manufacturing plant in Queensland, with the loss of some 200 jobs and approximately 20,000 export units and the closure of a production line that was estimated to have made some 244,000 units annually. Some of this production will no doubt now be picked up by Electrolux, but not all of it.

3.2. Air-conditioning Equipment

This sector includes all forms of air-conditioning equipment that use a refrigeration circuit to deliver cooled air. Equipment in this sector range from very small 'window-wall' integrated and sealed units that are installed to cool a single room, up to very large chillers that produce chilled air for distribution throughout very large buildings and spaces.

A good example of the effectiveness of large scale plant, which can often consume as much as 50% of all energy used in buildings in both the cooling and the distribution of the cooled air, are the systems that keep airport terminals or large exhibition spaces at stable, comfortable temperatures and levels of humidity.

Retail malls and food courts, where there are large numbers of people, huge numbers of hot lights and where cooking equipment operates, have very hard working systems. Large hospitals, with potentially hundreds of individual interior spaces with closely controlled air quality requirements, also have very large and complicated systems for maintaining air quality.

Air-conditioning is also now nearly ubiquitous in all new apartments and is becoming very common in private homes.

Stationary air-conditioning equipment consumed approximately 31.3%, in GWP terms, of all bulk ODS and SGGs imported into Australia in 2006. This material had a GWP of approximately 2.54 Mt CO_2-e. While the GWP of material consumed in this sector was lower than that of material consumed in refrigeration in 2006, air-conditioning equipment consumed slightly more material by weight with an estimated 1,444 metric tonnes of ODS and SGGs used in the sector. This is due to the dominance of different species of gas in air-conditioning compared to refrigeration. Nearly 75% (~1,073 metric tonnes) of the gas consumed in air-conditioning in 2006 was HCFC 22, a gas with a GWP of 1,500.

The largest user of ODS and SGGs in air-conditioning are the residential and small commercial air-conditioning systems known in the industry as wall hung split systems, window/wall units and split systems. These systems, of which there are an estimated 5.5 million installed, consumed some 910 metric tonnes of gas in 2006, of which more than 786 tonnes was HCFC 22 and the balance was HFC 410A (~103 tonnes) and HFC 407C (~20.3 tonnes).

More than 707 metric tonnes of the total 910 tonnes consumed in this class of technology was thought to have been used to replace gas lost from operating systems. The gas used in servicing the installed base of equipment was comprised of approximately 619 tonnes of HCFC 22, some 78 tonnes of HFC 410A and just under 10 tonnnes of HFC 407C.

The balance of the 910 tonnes was consumed by OEMs and during installation and commissioning of new systems. A total of 209 tonnes was consumed in this manner and was comprised of 167 tonnes of HCFC 22, approximately 25 tonnes of HFC 410A and slightly more than 10 tonnes of HFC 407C.

Larger air-conditioning systems that employ chillers, or involve 'roof-top' systems, precision control systems or VRV systems (variable refrigerant volume), consumed a total of about 533 metric tonnes in 2006, of which about 286 tonnes was HCFC 22. The balance of the material used in these classes of technology were HFC 134a (~121 tonnes), HFC 407C (~58.5 tonnes), HFC 410A (~24 tonnes) HCFC 123 (~23 tonnes) and HCFC Blends (~20 tonnes).

Some 319 of the 533 metric tonnes of refrigerant was used in servicing to top up gas lost from the estimated 11,000 chiller systems, 68,000 roof top systems, 9,900 VRV systems and 13,500 precision control systems estimated as operating at that time. Of this service gas, 224 metric tonnes was HCFC 22 with the balance comprising HFC 134a (~46 tonnes), HCFC blends (~20 tonnes), HFC 407C (~17 tonnes), HFC 410A (~7 tonnes) and HCFC 123 (~4 tonnes).

Of the total of 533 tonnes used in these systems some 215 metric tonnes is estimated to have been used by OEMs and during installation and commissioning of new systems. It is interesting to note that the volumes of HFC 134a used by OEMs, at 76 tonnes, was higher than the volumes of HCFC 22 at 62 tonnes, indicating a move away from HCFCs in this class of technology. Other material used by OEMs and at commissioning included HFC 407C (~41 tonnes), HCFC 123 (~19 tonnes) and HFC 410A (~17 tonnes).

Nearly 75% of all gas used in stationary air-conditioning equipment was an HCFC. This is more pronounced with the smaller equipment.

While all Australian air-conditioning equipment manufacturers have said they will cease using HCFCs by the end of 2008, demand for the gas is expected to remain fairly stable, as the demand for servicing the extensive stock of HCFC charged equipment rises. In recent years a spectacular surge in imports of HCFC pre-charged equipment has gone into the market and has begun to form a very large base of equipment that will underpin service demand for these gases for many years to come.

It is also likely that imports of HCFC pre-charged equipment will continue for some years into the future, particularly in the smaller appliances. Major international manufacturers of wall hung split systems have said they will cease importing HCFC charged equipment by the end of 2008, however that will still ensure that possibly 2 million domestic and light commercial air conditioning devices are imported during 2007 and 2008. Smaller manufacturers in South East Asia are also likely to continue using HCFCs (primarily HCFC 22) for some years to supply markets that allow the use of less efficient products, such as some parts of Asia, South America and the Middle East.

3.3. Mobile Air-conditioning

Mobile air-conditioning includes equipment found in buses, trucks, and private cars, and a number of unlicensed and off road applications including mining equipment, harvestors, mobile cranes, military vehicles and earthmoving equipment.

Mobile air-conditioning equipment consumed approximately 21%, in GWP terms, of all bulk ODS and SGGs imported into Australia in 2006.

All of this gas, with a GWP of approximately 1.74 Mt CO_2-e, was HFC 134a and the vast majority of it (more than 90%) was used in passenger vehicles. Approximately 229 metric tonnes of HFC 134a was used by domestic automotive manufacturers. A further 671 metric tonnes was consumed servicing air-conditioning systems in existing vehicles, while an estimated 373 metric tonnes was used replacing gas lost from vehicles that had some form of collision or compressor failure.

Thus a total of 1,044 metric tonnes of HFC 134a was estimated to have been used in 2006 to replace gas that had leaked from mobile air-conditioning systems or been lost as a result of accidents of equipment failure. This lost gas has a GWP equivalent to 1.36 Mt CO_2.

While the domestic manufacturing demand was likely to have been stable in 2007, the March 2008 announcement of the closure of the Mitsubishi manufacturing facility in Adelaide will reduce demand from vehicle OEMs, but not by more than 20%.

This area of demand is expected to grow slowly in line with growth in both registered and unregistered vehicles in the country. There are no systems on the market designed for use with alternative working gases, however some reports of use of hydrocarbons in HFC systems has been noted.

3.4. Foam

3.4.1. Domestic manufacture of foam products

An estimated 300 metric tonnes of various ODS and SGGs were imported for consumption in the manufacture of foam products in 2006. This gas is calculated to have an equivalent GWP of 305.6 kt CO_2e, of which about 75.9 kt CO_2e was attributable to HFCs and 229.7 kt CO_2e was attributable to HCFCs

These foam blowing agents equated to approximately 3.8% of total bulk ODS and SGG imports in 2006. Unlike almost every other major and minor application of ODS and SGGs, a significant proportion of this material is expected to be emitted to air in the year of import.

Polystyrene and polyurethane foams are used for their excellent insulating properties in both hot and cold insulation applications without the economies of scale to switch to alternatives. In insulated appliances, such as refrigerators and water heater storage tanks, the manufacturing includes blowing of foam directly into the shell of the appliance on the production line. Refrigerator manufacturers are predominantly global manufacturers and made the switch from CFCs to pentane in the mid-90s whereas most hot water storage applications still use HCFCs.

Aside from these instances of integrated foam insulation, the main foam product is known as rigid foam and is produced in blocks and cut to size to suit a wide variety of insulating applications that can range from refrigerators and hot water systems to large walk in cool rooms, building insulation panels and pre-fabricated structures.

A second application area is spray foam applications which are employed in varied environments to retrofit thermal or acoustic insulation and include the insulation for the inside of poultry sheds and livestock enclosures and, for instance, in retrofitting underfloor blown insulation in houses and other buildings. Industry sources commented that this market is quite small in Australia and is also an area where there is no option but to use a completely non-flammable propellant.

The insulating properties of a foam are in the gas filled spaces between the solid material, and different foam blowing agents have various insulating properties. The main ODS used in this application, HCFC 141b, has very good insulating properties. Alternatives, such as pentane, CO_2 and water do not provide the same degree of insulation in foam, although not by such a degree that most existing uses of foam cannot be satisfied with a foam manufactured using one of these alternatives.

Many of the major manufacturers who use foam blown with HCFC 141b, or who manufacture their own foams, are planning on a move away from HCFCs by the end of 2008.

The major manufacturers in Australia who produce their own foam products in-house include:

- Fischer and Paykel refrigeration manufacturing plant in Brisbane who have been using as much as 26 tonnes per annum but who, in April 2008, announced that they would be closing this plant in favour of expanding their larger facility in New Zealand;

- Rheem, the hot water manufacturer in Sydney who was reportedly the largest consumer of HCFC 141b in Australia, and who is in the process of planning a major refurbishment of plant for 2008 that will result in a switch to pentane.

- Dux, with a smaller and older plant and who apparently do not think they can justify the relatively large capital expense involved in refurbishing with the fireproofing equipment required switch to the flammable pentane. It was reported that they are likely to switch to HFCs in the next 6 months.

There are a number of 'system houses' who blend foam blowing agents and chemicals for foam manufacturers, large and small, and who produce foam to order for OEMs. This market is dominated by a few big players.

Market positions in terms of HCFC 141b consumption among the system houses are:

1. Huntsman;

2. ERA Polymers;

3. Chemind;

4. Ariel Industries (assessed as being in equal 3rd place with Chemind however with firm plans to exit the use of HCFC 141b entirely by end of 2008)

5. Australian Urethane Systems (insignificant consumption)

6. RLA Polymers (approx 200 kg of HCFC 141b per annum).

A number of smaller OEMs have been using R141b in commercial refrigeration, although once again some have recently switched or are planning migration to other systems.

BASF is a relatively new entrant to the market and is reportedly marketing itself very aggressively with pentane systems and is using no HCFC 141b.

The main commercial refrigeration manufacturers include Skope (switched to pentane), Orford Refrigeration (mix of water blown and HCFC 141b) and Williams Refrigeration that manufacture a variety of refrigerated cabinets (HCFC 141b, but under pressure from its parent company in UK to switch to something else). Coca Cola is reported to be applying pressure on these companies to switch to "total green" solutions for their vending machine and glass fronted fridge Coca Cola display cabinets.

In the refrigerated transport area Maxitrans is a refrigerated transport manufacturer still using HCFC 141b, whereas Bondor and Kingspan have migrated to pentane on sandwich panel but have not been able to do the same with manufacture of discontinuous panel (where foam is blown into a mould).

Interviews with market participants suggested that the majority of foam producers were ready to switch across to alternatives, however the market is still driven by economics and HCFC 141b is cheap, particularly when a manufacturer is tooled up to use it.

At present, system houses pay around $10 per kg for HCFC 141b and the alternatives cost closer to $15 per kg, plus require investment in new infrastructure. HCFC 141b costs approximately $5 per kg on the global market so systems houses are sticking to the most cost effective solution until an economic trigger point is reached or other issues arise that drive them to use alternatives.

Market intelligence indicates that importers and distributors of HCFC 141b make more profit selling HCFCs into refrigeration and air-conditioning applications and that these firms are working with foam manufacturers to consider alternatives. As the reducing HCFC import cap begins to restrict supply, and while demand for HCFCs continues to rise to service air-conditioning equipment, suppliers have become more motivated to move away from supplying the foam blowing industry.

There is some evidence that one and possibly two suppliers, however, are stockpiling the gas and will use their stockpiles to continue to supply HCFC 141b consuming foam manufacturers after the import cap starts to force up prices, delivering them with better margins from the foam blowing industry that is not prepared to invest in alternatives.

There are also several alternatives to be considered for manufacturing foam and there is no longer a 'one-size-fits-all' process that will deliver high quality insulating foams to all applications.

In the process of conducting the primary research for this inventory, very good interviews were conducted that provided great insight into the trends and immediate future of this industry which is clearly on the cusp of significant change.

3.4.2. Imports of Foam Products

One area in which research by the authors produced few tangible results was in the area of identifying quantities of ODS and SGGs imported in manufactured products not controlled under the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*. This was definitely the case in relation to foam product imports. Despite a lack of official sources, in the process of interviewing participants in this industry the opportunity was taken to ask about any knowledge of foam product imports.

One informant said that they had seen "A few jobs, some large ones that defy logic where product has been imported" including a "recent large job in WA." They were of the opinion that it was highly unlikely that any product is coming in that has been manufactured using CFCs.

Another significant player said that at different times they had tried to determine what foam blowing agents were used in imported product, however did not have much luck. However they claimed that some product with CFCs would still be coming into the country (but not much) and that a customer in New Zealand had recently been offered CFC-11 (forerunner to HCFC 141b).

However beyond these (conflicting) anecdotal views, there was no detailed data uncovered on imports of foam products.

3.5. Solvents

Accurate information on the demand for ODS and SGGs for use as solvents was difficult to come by. This study has identified at least 30 metric tonnes of HCFC 141b used in solvent applications and very small quantities of HCFC 225ca and HCFC 225cb that it is assumed are for solvent applications.

One informant claimed that they supply 60 metric tonnes of HCFC 141b that is used in an aerosol solvent application, however a search of every product that is available in Australia revealed no products containing HCFCs as solvents.

One piece of information that could be relied on was from Mike Selbie, Operations Director, Siemens (Water Division). He stated that Siemens' Windsor NSW manufacturing facility uses approximately 30 metric tonnes per annum of HCFC 141b. This facility is the Siemens global operations centre for water filtration products. They use HCFC 141b as a solvent where they extract oil and degrease in a two step process. They recycle the HCFC 141b in the process, however the entire 30 tonnes (GWP 39 kt CO_2-e) is emitted by the end of the process.

Siemans are aware that HCFC 141b is an ODS and that supplies of HCFC 141b are getting tighter and more expensive. Therefore, Siemans have been working on a project to replace HCFC 141b for the last year. Siemens claim there are two key barriers slowing progress:

- Water products are sold into global markets, so any changes to drinking water treatment products need to be approved by local global authorizing bodies which can be time consuming.
- Changing solvents can create technical issues downstream in the manufacturing processes that need to be addressed.

3.6. Aerosols

High quality information about the use of ODS or SGGs in aerosols proved to be difficult to come by.

This study estimates that as much as 25 metric tonnes of HFCs, with a GWP of approximately 39.6 kt CO_2-e, were consumed in aerosol products manufactured in Australia in 2006. However, there is a real possibility that some number of the aerosol tins containing an SGG manufactured in Australia were exported. At the same time, but based only on anecdotal information, it is likely that more SGGs in aerosols were imported than those exported.

One bulk gas supplier suggested that a reasonable estimate for overall market is 20 to 30 tonnes with approximately 18 tonnes being one customer. They also said that bulk demand for ODS and SGG from the aerosol market in Australia is declining and that most companies/applications that could switch away from use of HFCs as propellants have already done so.

Various parties suggested that there are apparently still applications where it is difficult to find replacements, often for flammability or toxicity reasons. Although there is a decline in local consumption, there are a number of imported products, some that don't have good justification for using HFC 134a as a propellent (this is particularly so in the case of some novelty products such as silly string). However, as the term ‘aerosol’ does not appear in any of the tariff or customs identification lists, it is impossible to tell how much material is imported.

Phillip Fleming, CEO Aerosols Association of Australia, reported that his Association has no real idea about how much ODS or SGG is imported in finished products. There are significant festivity and novelty products imported from China (such as ‘silly string’) which all have to use a non-flammable propellant. He stated that a lot of the novelty products in “$2 shops” could include product containing HFCs and other ODS or SGG propellants.

About four years ago Mr Fleming did a spot survey of suppliers of gas to the aerosol industry and at that time estimated that there was about 55 tonnes of HFC 134a being used in products manufactured in Australia. This survey has not been repeated since and there is no further information from other sources other than the estimate above from the bulk gas importer.

Fleming said that there are as many as 40 million aerosol tins exported from Australia every year, particularly to New Zealand where Johnson and Johnson, Ricketts and Gillette have all shut down their manufacturing capacity. On the basis of what is known, it is almost certain that the vast majority of those tins had non-ODS or non-SGG propellants.

Reportedly, one large user is said to use a formulated mix of HCFC 141b (as solvent)/HFC 134a (as propellant). Enquiries to them regarding the volumes used and possible exports were not responded to. A review of every product listed on the web did not reveal any that contained HCFCs as a solvent. However two products were identified, out of a couple of dozen aerosol products manufactured, as using HFC 134a as a propellant.

Past users of HFC 134a as a propellant were more forthcoming when they could report that they no longer manufactured in Australia. One manufacturer for instance used to consume approximately 20 tonnes per annum of HFC 134a as a propellant in aerosol sprays formulated to kill insects and fungus in jet planes. However they moved their entire manufacturing enterprise to Thailand and now ship their products from there to where ever they are required around the world, including importing some quantity to Australia.

3.7. Fire Protection

Approximately 31 metric tonnes of HFC 227ea and 48 metric tonnes of HFC 125 were imported into Australia in 2006. This material, with a combined GWP of approximately 224 kt CO_2-e, is the constituent of two of the major fire fighting substances used, marketed as FE-227 and FE-25 respectively.

Materials used in fire protection have very low leak rates. The whole point of the technology is to effectively store the material until the time when it may be needed to suppress fire. Because the cylinders in which fire fighting materials are stored also have to be checked for safety and efficacy every few years, the industry routinely captures and re-uses more than 95% of the material in cylinders being checked and serviced.

There is no publicly available data on the floor area covered by fire protection systems, although the information could be compiled using a blind, anonymous survey of the leading industry participants. There is very little data on levels of actual emissions during servicing of cylinders, and there is nothing on accidental discharges, although they do occur, however anecdotally they do not occur to any significant extent.

Table 7 below lists all ODS and SGG that could be used or found in fire protection equipment in Australia.

Table 7. ODS and SGGs in fire protection equipment

Product	Use	Other Names
CFC 11	May be found in some powder fire extinguishers	
FE-227	This is a total flooding extinguishing agent used as a replacement for Halon 1301	Heptafluoropropane or HFC 227e
FE-25	Commonly used in inerting and explosion suppression applications and to retrofit existing Halon 1301 systems	Pentafluoroethane or HFC 125, FE-36
FE-13	Total flooding agent	Trifluoromethane or HFC-23, FE-13
FE-241	Functions both as a total flooding agent for non-occupied spaces and as a streaming agent	Chlorotetrafluoroethane or HCFC-124, FE-241
FM200	Typical applications could include chemical storage areas, clean rooms, communications facilities, laboratories, museums, robotics and emergency power facilities	Heptafluoropropane or HFC-227ea
Halotron I and II	Halotron I is typically used for streaming and local applications. Halotron II is intended for total flooding	Halotron I: HCFC based. Blend B Halotron II: HFC based.
HCFC 22	May be found as a propellant in some powder fire extinguishers	
HFC 134a	May be found as a propellant in some powder fire extinguishers	
NAF S-III	Typically used as a flooding agent. It is a replacement for Halon 1301. It is effective on Class A, B and C type fires	HCFC Blend A
NAF P-III	Typically used as a streaming agent. It is a replacement for Halon 1211. It is effective on Class A, B and C type fires	HCFC Blend C
NAF P-IV		HCFC Blend E

The Fire Protection Association of Australia reports that the ODS or SGGs most commonly used for fire fighting in Australia are;

- HFC 227e known as FE-227,

- HFC 227ea known as FM-200,
- A HCFC blend known as NAF S-III, and
- A HCFC blend known as NAF P-III.

Inert gas extinguishing agents, such as Inergen, Novec 1230 and CO_2, get about 50% of the annual market in Australia while SGGs comprise the other 50%. There are still an unknown number of HCFC systems in operation and being maintained. Tyco Wormald, the largest provider of fire protection systems in Australia, reported that they were still managing about 10 tonnes of installed NAF S-III, down from the peak of more than 80 tonnes at the beginning of the decade.

There is no information available on the number of small and portable fire extinguishers imported into the country, nor therefore any that are imported with ODS or SGG propellants. There are anecdotal suggestions that some of these devices do come into the country however there is no Customs or industry data collected.

3.8. Electronics

Not all of the applications listed in Table 4 were found to be substantial in Australia. For instance, while there was some confirmation of PFC-based products being used as inert heat transfer fluids in the vapour phase reflow soldering process, we were not successful in actually finding any companies who admitted to using any of these materials. In fact a response provided by a leading member of Australian Electronic Equipment Manufacturers Association suggested that there was no specialized applications in contract electronics manufacturing in Australia that use HFCs or PFCs, but that nitrogen was used.

Similarly, during conversations with bulk gas importers no significant customers in the electronics industry were reported.

However another of the AEEMA members reported by email, very late in the intelligence gathering phase, that various formulations are available on the market to suit different temperature requirements and applications. For example, FC-70, SF-2 from 3M, and Galden LS/HS from Solvay Solexis for vapour phase reflow soldering.

It was further reported by the same informant that, “HFCs such as HFC 134a and HFC 152a are commonly used as propellants in pressurized containers or aerosol cans for products packaged for, for example, dust removal, circuit freezing, assembly cleaning or conformal coatings applications”.

However, at this stage there is very little evidence of these products being widely available or used in Australia. No volumes of imported PFCs or HFCs, in either bulk gas or finished products, were identified definitely going to these applications.

We conclude that it is highly likely that there is some commercial use of PFCs and HFCs in the electronics industry as far as it exists in Australia, however the volumes are unknown and are almost certainly very small in the scheme of things.

4. The Bank and Emissions

4.1. Estimates of Installed Base of Various Refrigeration and Air conditioning Machinery

In the process of conducting this research, the estimates of the stock of ODS and SGG containing equipment, originally developed as part of the '*Cold Hard Facts*' study, were reviewed, and in some areas considerably extended to provide the basis on which to calculate the bank of working gas.

On the basis of the estimated stocks of equipment, and using average gas charges, the working gas in Australia is estimated at 30,574 metric tonnes of ODS and SGGs, with a total GWP equivalent to approximately 49.7 Mt of CO_2.

Figure 3 illustrates the relative proportions of the main gas species estimated to comprise this working bank of gas.

Figure 3. Bank of Working Gases In Australia 2006 Metric Tonnes

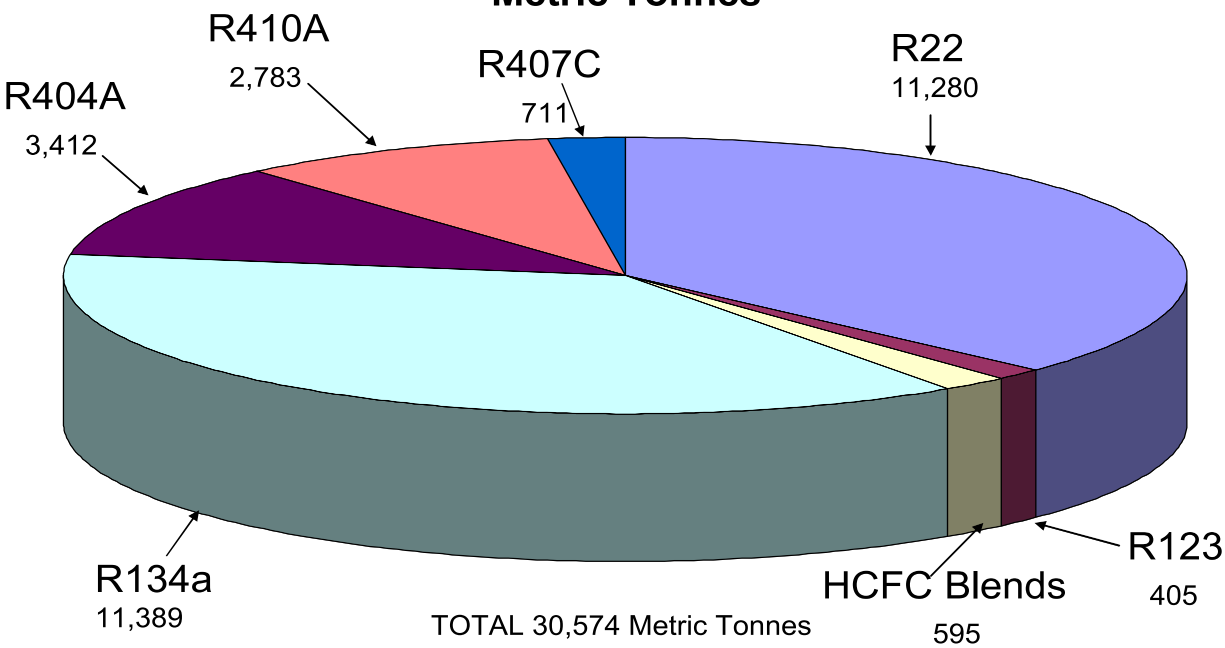


Table 8 lists the numbers of the various classes of ODS and SGG containing equipment estimated to exist in Australia along with estimates of the working gas employed in each.

Table 8. Estimates of Machinery and Bank of Working Gas (in metric tonnes)

	Inventory	ODS	SGG
Domestic Refrigerators and Freezers	10,979,000	122	1,086
Domestic and Small Commercial Air conditioning	5,546,000	6,919	3,055
Roof Top Packaged	68,400	751	83
Precision Control and VRV systems	23,400	365	90
Chillers: Commercial Air conditioning	11,000	1,918	1,163
Chillers: Food Chain, Industrial & Other	11,900	704	423
Large Commercial Refrigeration: Cold Storage	9,460,000 m^3	106	-
Large Commercial Refrigeration: Supermarkets	3,675	202	1,582
Medium Commercial Refrigeration Equipment (Primary Industry, Catering, Shop, Hospitality, Clubs, Pubs, Hotels & Liquor Retailing)	87,600	417	1,791
Small Commercial Refrigeration & Self Contained Equipment	228,000	62	554
Milk Vat Applications (Dairy Industry)	11,000	352	88
Refrigerated Vehicles	16,400	10	85
Passenger Vehicles with AC	10,318,300	-	6,191
Light Commercial Vehicles with AC	1,945,200	-	1,264
Trucks and Buses with AC	514,200	-	624
Rail and Unregistered Vehicles^	40,800	17	126
Small Vehicle Powered Refrigerators	30,000	-	3
Fishing Vessels longer than or = 10m	2,130	338	84
Totals	***29,837,005***	***12,283***	***18,292***

4.2. The ODS and SGG Bank and Emissions

Based on the stock of equipment, and using industry informants to guide the selection of reasonable average gas charges for the various classes of equipment and types within each class, the bank of working gas was calculated.

Table 9. Estimates of the Bank of Working Gas by equipment type, gas retained in 'end-of-life' equipment and losses through leakage in 2006

End Use Technology	Existing Bank (metric tonnes)	Range of leak rates applied[7]	Estimated leakage 2006 (metric tonnes)	EOL Equipment (contained tonnes)
Stationary AC				
Residential and Light Commercial	9,974	1% - 11.9%	707	361
Commercial	4,370	1% - 11.9%	319	146
Stationary Refrigeration				
Supermarket Industry Systems	1,784	15% - 30%	285	36
Small and Medium Commercial Refrigeration	3,386	5% - 20%	333	50
Cold Storage and Process Refrigeration	1,232	7% - 20%	109	39
Domestic Refrigeration	1,086	2%	3.3	68
Transport Refrigeration				
Truck	95	30%	15.6	9
Other Mobile	425	30% - 35%	141.2	0[8]
Mobile AC				
Registered	8.079	9% - 12.5%	733[9]	331
Unregistered	143	9% - 12.5%	12.2	13
Total	***30,574***		***2,658***	***1,053***

Table 9 lists this bank of gas allocated across equipment types. Further, using estimates of the working life of each class of equipment, developed originally for the '*Cold Hard Facts*' study, and applying acceptable leak rates to each class and type of equipment, the volume of ODS and SGGs

[7] Appendix 5 breaks down categories of equipment in greater detail by rated output and attributes leak rates that take into account the variation depending on the gas species employed. Notably leak rates for HFC charged systems are generally at the lower end of the range compared to HCFC charged systems due to different operating pressures amongst other factors. This observation does not apply in mobile systems which are universally HFC charged systems.
[8] This category is almost entirely working gas in the fishing fleet and some small quantities attributed to refrigerated containers. We assume that virtually no refrigerant makes it to retirement due to high leak rates, harsh conditions and systems that are essentially kept operating indefinitely.
[9] Including gas replaced across all passenger vehicles, light commercial vehicles, trucks and buses. If gas replaced as a result of crash repairs and compressor failure were to be included this would add another 396 metric tonnes to this category.

expected to be contained in equipment approaching the end of its useful life was calculated. Leak rates are included at Appendix 5.

It is calculated that approximately 1,053 metric tonnes of ODS and SGGs are contained in equipment reaching the end of its useful life in 2006. This end-of-life (EOL) gas has a GWP equivalent to 1,503 kt CO_2.

Using the leak rates selected, it was calculated that the bank of ODS and SGGs is incurring losses to atmosphere of approximately 2,658 metric tonnes per annum, with a GWP equivalent to 4,573 kt CO_2. This quantity of losses is equal to approximately 56% of all of the bulk imports of ODS and SGGs into Australia in 2006.

Thus, it could be concluded that more than half of all bulk imports are being used to replace gas lost via leakage from working equipment.

Table 10 presents estimates of annual leakage, and gas contained in end of life equipment, by gas type, to allow calculation of the GWP of estimated leaks and EOL losses to atmosphere.

Table 10. The Bank of Working Gas and Leakage by Gas Type, 2006

2006	GWP	Estimated Bank			Emissions		
		Existing (Tonnes)	Retiring (Tonnes)	Retiring (%)	Leakage (Tonnes)	Leakage (kt CO_2-e)	Retiring (kt CO_2-e)
HCFC 22	1500	11,280	520	49%	1167.5	1751	780
HCFC 123	90	405	25	2%	4.1	0.4	2
HCFC-Blends	1500	595	39	4%	74.6	112	58
HFC 134a	1300	11,389	435	41%	871.4	1133	565
HFC 404A	3,260	3,412	26	2%	423.7	1381	84
HFC 410A	1,725	2,782	-	-	85.5	147	-
HFC 407C	1,526	711	8	1%	31.4	48	13
R-Mix	2823	-	-	-	-	-	-
CFCs[10]	-	?	?	-	?	?	?
Total		***30,574***	***1,053.2***	***100%***	***2,658.2***	***4,573***	***1,503***

Thus, estimates of ODS and SGG leaks from the working bank, combined with gas in end-of-life equipment, and assuming all gas in EOL equipment is released to atmosphere, would indicate that a total of 3,711 metric tonnes of ODS and SGGs with a GWP of 6,076 kt CO_2-e was released to the atmosphere in 2006.

This estimate of leakage does not include losses as a result of vehicle collisions or other ‘catastrophic’ failure of mobile air-conditioning systems. Using an estimate derived from sales data on replacement compressors for vehicles it is possible to conclude that as much as 5% of all vehicles suffer some form of catastrophic loss of gas from their air-conditioning system. This would be equivalent to a further 396 metric tonnes of HFC 134a per annum, with a GWP of approximately 515 kt CO_2-e in 2006.

[10] This project was not required to investigate the bank of CFCs in the economy, nor estimate losses to air, however data collected by Refrigerant Reclaim Australia at point of destruction of reclaimed mixed refrigerant gases (tabulated on page 39) indicate that there could be a considerable bank of CFCs still in use, in the range of some hundreds of metric tonnes, which in the opinion of the authors, would almost entirely be contained in pre-1994 domestic refrigerators and freezers.

On an application basis, and including this estimate of 'catastrophic' losses from mobile air-conditioning, the following picture emerges for losses from registered vehicles (Table 11).

Table 11. Leakage and Losses from Registered Mobile Air-conditioning, 2006

	Service Consumption (Tonnes)	Crash Consumption (Tonnes)	Total Consumption (Tonnes)	Retiring Bank 2006	GWP Total Consumption + Retiring Bank (kt CO_2-e)
Passenger Vehicles	557.19	309.55	866.74	252.42	1,454.90
Light Commercial Vehicles	113.79	63.22	177.01	51.55	297.13
Total Passenger	**670.98**	**372.77**	**1043.75**	**303.97**	**1,752.03**
Rigid Trucks: Light	3.91	2.17	6.08	2.48	11.13
Rigid Trucks: Heavy	25.93	14.40	40.33	11.52	67.41
Articulated Trucks	6.45	3.58	10.04	2.87	16.77
Non Freight Trucks	0.83	0.46	1.29	0.53	2.37
Total Trucks	**37.12**	**20.62**	**57.74**	**17.40**	**97.68**
Commuter Vehicles/Buses	4.42	2.46	6.87	2.14	11.71
Buses (>7m in length)	20.25	0.00	20.25	7.20	35.69
Total Buses	**24.67**	**2.46**	**27.12**	**9.34**	**47.40**
Total Registered MAC	***732.77***	***395.85***	***1,128.62***	***330.70***	***1,897.11***

Emissions from various categories of stationary air-conditioning equipment by species of gas is shown in Table 12. Emissions from stationary refrigeration are shown at Table 13 by equipment type and gas species. Emissions from Transport Refrigeration are shown in Table 14 by equipment type and gas species.

Table 12. Leakage from Stationary AC by Gas Species (in metric tonnes and CO_2-e)

Gas Species (metric tonnes)	HCF C22	HCF C 123	HCF C Blend	HFC 134a	HFC 410A	HFC 407C	Total Service Consumption (metric tonnes)	Total Consumption (kt CO_2-e)
Residential & Light Com AC								
Wall Hung Split Systems	303.41	-	-	-	49.92	5.87	359.20	609.54
Split Systems	298.23	-	-	-	27.53	3.18	328.93	559.42
Window/Wall Units	17.70	-	-	-	0.57	0.14	18.42	32.99
Portable	0.23	-	-	-	0.32	0.68	1.23	3.39
Total Residential and Light Commercial	**619.56**				**78.34**	**9.87**	**707.78**	**1,200.04**
Commercial AC								
RT Packaged	75.10	-	-	-	0.58	5.26	80.94	135.71
Chillers < 530 kW	16.59	-	2.26	5.27	0.36	1.18	25.67	42.70
Chillers > 530 & < 1055 kW	51.09	-	10.52	16.60	1.21	3.62	83.03	134.83
Chillers > 530 & < 1055 kW (HCFC-123)	-	0.38	-	-	-	-	0.38	1.0752
Chillers > 1055 kW	38.14	-	6.93	24.37	-	5.57	75.01	116.34
Chillers > 1055 kW (HCFC-123)	-	3.67	-	-	-	-	3.67	10.28
VRV Systems	-	-	-	-	4.99	0.55	5.54	10.93
Precision Control AC	43.38	-	-	-	-	1.08	44.46	76.59
Total Commercial	**224.30**	**4.05**	**19.72**	**46.23**	**7.14**	**17.26**	**318.71**	**519.60**
Total Stationary AC	***843.86***	***4.05***	***19.72***	***46.23***	***85.48***	***27.14***	***1,026.48***	***1,719.64***

Table 13. Leakage from Stationary Refrigeration by Gas Species (in metric tonnes and CO_2-e)

Consumption - Service (Tonnes)	HCFC 22	HCFC Blends	HFC 134a	HFC 404A	Total Tonnes	Total Consumption kt CO_2-e
Supermarket Industry/Systems						
Small	11.70	-	-	17.55	29.25	77.10
Medium	17.25	-	-	101.25	118.50	359.40
Large	18.43	-	-	118.46	136.89	417.51
Total Supermarket and Industry	**47.38**	**0.00**	**0.00**	**237.26**	**284.64**	**854.02**
Small & Medium Commercial Refrigeration						
Self Contained & Small Com Refrigeration	-	-	8.86	2.22	11.08	18.75
Clubs, Pubs, Hotels & Liquor Retailing	14.82	4.64	34.21	37.87	91.54	201.48
Catering & Hospitality	1.12	-	17.96	18.71	37.79	86.24
Retail Food	22.87	7.19	14.70	52.06	96.81	240.64
Cool Rooms (Primary Industry)	4.59	1.42	1.89	1.70	9.61	18.37
Milk Vat (Primary Dairy) Industry	52.80	17.60	-	13.20	83.60	164.47
Domestic Refrig with R22	2.44	-	-	-	2.44	4.15
Total Small & Medium Commercial	**98.64**	**30.85**	**77.62**	**125.76**	**332.87**	**734.10**
Cold Storage & Process Refrig						
Cold Storage	21.12	-	-	-	21.12	35.91
Food Chain, Industrial & Other						
Small Chillers	3.56	0.12	-	2.07	5.75	13.01
Medium Chillers	33.18	4.52	-	19.08	56.78	126.74
Large Chillers	13.80	3.25	4.22	4.22	25.50	48.57
Total Cold Storage and Process Refrig	**71.66**	**7.89**	**4.22**	**25.37**	**109.15**	**224.23**
Total Stationary Refrigeration	**217.68**	**38.74**	**81.84**	**388.39**	**726.66**	**1,812.35**

Table 14. Emissions from Transport Refrigeration by Gas Species (in metric tonnes and CO_2-e)

Service Consumption (Tonnes)	HCFC 22	HCFC Blends	HFC 134a	HFC 404A	Total	GWP Total Consumption kt CO_2-e
Truck: Trailer & Inter-Modal	0.52	0.52	-	4.66	5.70	17.00
Truck: Diesel Drive: Truck	0.29	0.29	-	2.60	3.18	9.50
Truck: Off Engine/Vehicle Powered (Option Electrical Stand-by)	0.61	0.61	0.61	4.90	6.74	18.92
Total Truck	**1.42**	**1.42**	**0.61**	**12.16**	**15.62**	**45.42**
Fishing Vessels	103.39	14.77	-	21.10	139.26	271.14
Vehicle Powered Refrigerator: Small	-	-	0.01	-	0.01	0.01
Refrigerated Containers (20ft & 40ft Marine Containers)	-	-	-	2.00	2.00	6.52
Total Other Mobile	**103.39**	**14.77**	**0.01**	**23.10**	**141.27**	**277.67**
Total Transport	***104.81***	***16.19***	***0.62***	***35.26***	***156.89***	***323.09***

Unlike in the case of mobile air-conditioning systems, which are universally charged with HFC 134a, the estimates of retirements of end-of-life equipment do not allow accurate disaggregation of the retiring equipment by gas species, making any estimate of the GWP of gas contained in EOL equipment difficult. However, based on the estimates of retiring equipment and the average gas charges applied, it could be expected that, in addition to the leakage of gas set out in the above three tables:

- An additional 506.5 metric tonnes of gas is contained in retiring stationary air-conditioning equipment equivalent to possibly 1,114 kt CO_2-e;
- An additional 166.14 tonnes of gas is contained in retiring stationary refrigeration equivalent to possibly 348.9 kt CO_2-e; and
- An additional 9.4 tonnes of gas is contained in retiring mobile refrigeration equivalent to possibly 19.4 kt CO_2-e.

While the global warming potential of these volumes of gas could be roughly estimated, the proportion of this gas that actually is lost to air is more uncertain as, in some classes of equipment covered by this EOL estimate, recovery rates would be very high (such as with large commercial chillers and large supermarket refrigeration systems). On the other hand, smaller commercial and residential equipment is likely to have quite low rates of recovery under present practices.

4.3. Forecasts of EOL Growth

Recent trends in equipment imports and sales, first identified in the *Cold Hard Facts* study and explored in the *HCFC Bank in Australia*, have resulted in rapid growth in both the stock of equipment and in the working bank of gas. The report into the *HCFC Bank in Australia* noted that this included a very rapid growth in the working bank of HCFC 22 between 2000 and 2006.

Using the same assumptions and values employed to estimate volumes of ODS and SGGs in EOL equipment in 2006, a forecast can be made of EOL equipment and contained ODS and SGGs at points in the future. For the sake of this exercise, we have selected 2018 as the forecast date, being the point in time when a large percentage of the equipment installed up to 2006 will be expecting to reach end-of-life. Because we know with some certainty the species of gas in that equipment, we can estimate the expected GWP of that EOL gas assuming that it is all released to atmosphere.

As a result, we estimate ODS and SGGs in EOL equipment in 2018 will be 3,203 metric tonnes. This amount could be more than 3 times greater than the 2006 volume, with a GWP equivalent to 5.54 Mt CO_2. The rapid growth in the bank of working gas, and the stock of equipment, increases the need for, but not necessarily the economic opportunity for expanded recovery activity.

Table 15 sets out estimates of gas contained in EOL equipment in 2018 by type of equipment.

Table 15. ODS and SGGs Contained in End-Of-Life equipment in 2018

	Retiring (E.O.L.) 2018 Metric tonnes
Stationary AC	
Residential & Light Com AC	1865
Commercial	178
Stationary Refrigeration	
Supermarket Industry/Systems	57
Small & Medium Commercial Refrig.	94
Cold Storage & Process Refrig	75
Domestic Refrig.	87
Transport Refrigeration	
Truck	21
Other Mobile	21
Mobile AC	
Registered	788
Un-registered	18
Total metric tonnes contained	***3,203***

5. Existing ODS and SGG Recovery and Opportunities for Expansion

Very good data on recovered and destroyed ODS and SGGs are available from Refrigerant Reclaim Australia (RRA), the industry managed product stewardship scheme that pays a small bounty on every kilogram of refrigerant gas returned for destruction.

This information provides the only reliable records available of the level of ODS and SGG recovery being undertaken.

In 2006, RRA destroyed a total of 332.6 metric tonnes of recovered refrigerants of which 36.7 tonnes were CFCs, 187 tonnes were HCFCs and 103.8 tonnes were HFCs. This material had an aggregated GWP of 452 kt CO_2-e.

Table 16. Refrigerant reclaimed and destroyed, 2004-2007

		CFC kg	HCFC kg	HFC kg	Other kg	HC kg	Total kg
2004	kg	44,968	136,887	52,080	1,669	966	236,570
	% of total	19%	58%	22%	1%	0.4%	
2005	kg	42,194	150,488	68,510	1,760	1,577	264,529
	% of total	16%	57%	26%	1%	0.6%	
	Diff	-2,774	13,601	16,430	91	611	
2006	**kg**	**36,712**	**187,015**	**103,813**	**2,946**	**2,132**	**332,618**
	% of total	**11%**	**56%**	**31%**	**1%**	**0.6%**	
	Diff	**-5,482**	**36,527**	**35,303**	**1,186**	**555**	
2007	kg	37,277	234,509	133,568	3,355	2,308	411,017
	% of total	9%	57%	32%	1%	0.6%	
	Diff	565	47,494	29,755	409	176	

As Table 12 shows, there has been strong growth in total volumes of refrigerant destroyed since 2005. RRA put this down to the impact of the Australian Refrigeration Council's licensing scheme. They predict continuing 30% year on year growth in total volumes for several years to come as the licensing scheme, and new codes of practice, underpin greater levels of compliance across the workforce.

Even in CFCs, recoveries of which had appeared to be in strong decline (one would assume as a result of remaining CFC-charged equipment rapidly reaching end-of-life), 2007 saw a slight increase in the quantities recovered and destroyed.

The data above indicating volumes of particular species recovered and destroyed is derived from gas chromatograph analysis of the material introduced to the electric arc furnace at destruction. This gas chromatographic analysis gives very accurate values on the individual species of gas. However the species identified are the constituent parts of many of the commercial formulations or blends.

On the basis of this information, we have reconstructed a likely mix of the species and blends that made up the total of the destroyed gas and these are listed in Table 17 and Table 18, with the make up of the residual gases presented for destruction listed in Table 19.

Table 17. Analysis of RRA Data for HCFCs

HCFC Analysis	Gas Destroyed (kg)	
HCFC 22	186,100	
HCFC 124	915	
Total	**187,015**	
Reconstruction	kg	%
HCFC 409	3,661	2%
HCFC 408	915	0.5%
Other HCFC blends	458	0.2%
Deduct HCFC 22 in blends	3,021	-
HCFC 22	183,079	97%
Total	**188,114**	**100%**
Difference (in Other)	1,098	-

Table 18. Analysis of RRA Data for HFCs

HFC Analysis	Gas destroyed (kg)	
HFC 134a	61,847	
HFC 125	18,307	
HFC 152a	8,920	
HFC 32	8,907	
HFC 143a	5,832	
	103,813	
Dissection	kg	%
HFC 404A/507A	10,822	10%
HFC 407C	3,994	4%
HFC 410A	15,977	15%
Blends (other)	616	1%
HFC 134a (Blends)	1,431	2%
HFC 134a (Auto Service)	36,350	35%
HFC 134a (Comm Ref/AC	24,166	23%
HFC 125a	8,920	9%
Other	1,638	2%
Total	**94,893**	**100%**

Table 19. Analysis of RRA data for residual species

Residual Analysis	Gas destroyed (kg)
HFC 23	18
Other F Gas	2,929
HCs	2,132[11]
Total	**5,078**

[11] One observation that must be made is that more than 2 tonnes of hydrocarbons were recovered and destroyed. This is indicative of the rate of application of hydrocarbons as a working gas in air-conditioning. It is assumed that most of this material would come from mobile air-conditioning systems.

It is not safe to assume that recoveries for destruction occur from the various stocks of equipment in any direct proportion to the working bank of gas in that type of equipment.

Based on interviews with industry participants in the course of this project the following conclusions can be made.

1. There is no evidence of significant recoveries from end-of-life residential appliances, sealed air-conditioning equipment (such as window/wall units that are often removed by people who are not licenced refrigeration mechanics) and very little (<3%) from passenger vehicles. With the recent introduction of mandatory legislation requiring the reclaim of refrigerant from systems, more refrigerant is being reclaimed and sent to Refrigerant Reclaim Australia. Previously the practice was to 'pump down' equipment, releasing the residual gas in interconnecting pipe-work to air, and sending the semi-charged condensing unit to a point metal recycling depot or a landfill.

2. Since the advent of the transition away from CFCs in the 1980s, a strong culture of gas recovery and reuse has developed in those sectors where plant and equipment is large and thus either attended by full-time engineers or very closely monitored and regularly serviced. This was reported to be particularly the case in supermarkets where it was reported that refrigerant is routinely recovered for re-use, not for destruction. Similar attitudes are encountered in the cold chain and with large commercial chillers. This indicates that, at least in some sectors, re-use of recovered gas is likely to be much more widespread than previously realised.

3. There is some anecdotal evidence that SGGs in transport refrigeration are similarly well managed. However, it is quite clear that only a very small percentage (<3%) of all gas thought to be contained in end-of-life passenger vehicles and other registered and unregistered mobile air-conditioning systems is recovered.

In general terms there is an expanding awareness and, it was commonly suggested, increasing compliance with the ARC licensing requirements for handling of SGGs. However, even given that there is possibly more recovery for re-use than might have been expected, the volumes of gas imported and thought to be used for recharging of leaky systems in 2006 (~2,641 metric tonnes) and the volumes of gas estimated to be in end-of-life equipment in that year (1,053 metric tonnes) make the volume actually returned for destruction of 336 metric tonnes look quite small.

The large majority of refrigerant recovered is from the commercial refrigeration and air-conditioning industry, with increasing quantities coming from the mobile air-conditioning service industry.

Refrigerant Reclaim Australia and ARCtick have successfully conducted targeted campaigns to educate the commercial refrigeration and air-conditioning sector on best practices. In general, operators in this area are better trained and rely on having their licences for a living.

It is difficult to determine the amount of refrigerant reclaimed and returned for destruction that comes from end-of-life equipment in the commercial refrigeration and air-conditioning area, versus recovery in the course of service. However initial calculations suggest end of life reclaim to account for more than 30% and less than 60%.

Further work regarding refrigerant recovery is required for each segment. However, some preliminary benchmarks were developed during the study from a small sample of 40 licensed commercial airconditioning technicians. Each technician used 147 kg of virgin refrigerant per year and reclaimed 13 kg of refrigerant per year. Their records did not encompass re-use of refrigerants, nor distinguish between end-of-life or service recovery.

With regard to smaller split systems and residential systems current practice would suggest that the vast majority of equipment that reaches end-of-life is removed by a builder or DIY renovator and is dumped without being evacuated by a refrigeration technician. As such, it is expected that recoveries from this large class of equipment are negligible.

While there is presently no way of assessing what volumes of SGGs are unnecessarily vented that might otherwise have been recovered for destruction, the refrigerant handling licensing scheme is almost certainly reducing the volume vented to air and simultaneously increasing the volume of SGGs recovered and reused.

Based on interviews with industry participants, and using our understanding of the stock of equipment, an analysis of the end-of-life volumes of SGGs is presented in Table 20.

The largest volumes of gas from equipment at the end of its useful life is not directly proportional to the stock of equipment and the bank of gas because allowances have been made for those equipment types likely to be managed by professional engineers.

Table 20. SGGs in End of Life Equipment 2006 and 2018 (metric tonnes)

	Existing Bank	Retiring (EOL) 2006	Retiring (EOL) 2018
Stationary AC			
Residential & Light Com AC	9,974	361	1865
Commercial	4,370	146	178
Stationary Refrigeration			
Supermarket Industry/Systems	1,784	36	57
Small & Medium Commercial Refrig.	3,386	50	94
Cold Storage & Process Refrig	1,232	39	75
Domestic Refrig.	1086	68	87
Transport Refrigeration			
Truck	95	9	21
Other Mobile	425	0	21
Mobile AC			
Registered	8,079	331	788
Un-registered	143	13	18
Total	***30,574***	***1,053***	***3,203***

The largest volume of end-of-life SGGs is in the stationary air-conditioning area. Industry intelligence suggests that it is well known that unlicensed operators and installers without reclaim equipment still operate in the residential and light commercial markets. Older window units and other sealed units are sent to scrap with a significant charge. In fact on the basis of the age of the stock of equipment, in this area, over 50% of the retiring stock in 2006 is estimated to be window/wall units which are predominantly sealed units that are not pumped-down when removed.

They are simply sent to scrap for destruction and release of their gas charge, all of which will be HCFCs.

The next largest opportunity is in the area of registered mobile air-conditioning units. Some 600,000 vehicles are reaching the end of their useful life every year in Australia and SGGs are recovered from possibly as little as 2% of these vehicles, while as many as 60% of them are estimated to still have a gas charge in the air-conditioning equipment when they get to the scrap yard.

Refrigerant Reclaim Australia assert that growth in gas volumes returned for destruction in 2006/07 is almost entirely due to the new regulatory environment that makes recovery and safe disposal of ozone depleting and synthetic greenhouse gas refrigerants mandatory. These requirements have catalysed the re-engagement of the automotive sector which has significantly increased returns of HFCs.

Across all smaller equipment classes, domestic refrigeration and freezers, small air-conditioning units and mobile air-conditioning in passenger vehicles, while the volumes of gas per piece of equipment is small, the vast majority of this equipment ends up in the hands of scrap metal merchants, a business in Australia which is concentrated in relatively few hands.

An obvious opportunity to increase recoveries from end-of-life equipment would involve making inspection and recovery of gas from equipment at scrap metal yards mandatory before the equipment can be processed.

The existing bank of CFC/HCFC foam is likely to be large due to activity prior to the global switch to pentane in the mid 1990s. A lot of old refrigerators will be CFCs. The industry stopped using CFCs in large production quantities in Australia right up to the cut off in 1994 because CFCs had better performance characteristics and cost benefits. There was not a lot of HCFC 141b activity prior to the cut-off. Most participants admitted waiting until the last minute before switching to HCFCs.

Recent increases in recoveries of all gases have demonstrated that an effective mix of regulation, training and certification, licencing and financial incentives can improve recovery of unwanted ODS and SGG.

6. HCFC Demand and Projections

During the first half of 2007 an extensive research and modeling exercise was undertaken to generate a forecast for future demand for HCFCs in Australia. The following section is extracted from various parts of that study and included in this report. The findings of the work are highly relevant in terms of future trends in the overall Australian demand for and end uses of ODS and SGGs.

HCFCs are a class of synthetic gases subject to international agreements under the Montreal Protocol. The most common of these gases is HCFC-22, also know as R-22. It was first commercialized as a refrigerant in the 1930's and has been used continuously since that time. It is a transitional ozone depleting substance with an ozone depleting potential (ODP) of 0.055 that grew rapidly in the 1980's and is the most common refrigerant used in air-conditioning and refrigeration applications, making up the vast majority of HCFC imports into Australia over the last decade.

The balance of HCFC imports used in refrigerating applications are mostly of two gas species, HCFC 123 and 124, that are used in large chillers or in refrigerant gas blends. There is also a reasonably large volume of the gases HCFC 141b and 142b that is primarily used in the manufacture of rigid insulating foams.

The task of estimating future demand of HCFCs, and comparing it with the agreed cap on HCFC imports out to 2020, was completed in two phases. Phase one involved constructing a robust model of the bank of working gas using the data developed in the '*Cold Hard Facts*' study, plus estimating volumes of gas used in the production of rigid foams and in other uses. The model created in Phase One was then used to estimate future demand for HCFCs under a business-as-usual policy environment.

Phase two involved calculating losses from that stock of equipment plus analyzing data on HCFC bulk imports (for which there was nearly 10 years of data) to estimate:

- what HCFCs were presently used and thus were likely to be required in the future to service the existing stock of equipment;
- then to extrapolate future demand for HCFCs based on estimates of changes to the stock of equipment, and changes to manufacturers' consumption based on interviews with end users of HCFCs.

This was done using two methods, a top down and a bottom up approach.

6.1. Projection Method 1: Top Down

This method uses a simple extrapolation of the trend derived by fitting a line through recorded bulk imports of the HCFC gas import data available from 1997 to the present.

The resulting trend line was then extrapolated forward on the basis of a straight linear decline from the last actual data point as outlined in the table below.

Table 21. Parameters of HCFC Demand Forecasts to 2020

Refrigerant	Upper Limit ODP Tonnes		Lower Limit ODP Tonnes		Comments
	Start	End	Start	End	
HCFC-141b	2006 Actual	4 tonnes in 2015	2006 Actual	2 tonnes in 2012	Some applications will be difficult to find effective and affordable 141b substitutes for. Best possible case is 2 to 3 years before economics gives cause to switch and 1 to 2 years for end product approval/certification. If industrial users are slow to respond to rising prices for 141b there could be significant demand for another 8 to 10 years.
HCFC-142b	2006 Actual	zero in 2015	2006 Actual	zero in 2012	See trend chart for more comment. Suggests upper and lower limits could possibly be higher than indicated. The 2007 import statistics of HCFC-142b will provide more insight into the rate of substitution.
HCFC-124	2006 Actual	2 tonnes in 2015	2006 Actual	1 tonne in 2010	Large majority of applications (gas blends and crane AC should find substitutes), however a few may be difficult or take longer than mainstream AC applications.
HCFC-123	2006 Actual	zero in 2017	2006 Actual	zero in 2013	See trend chart and associated worksheets detailing assumptions on large chillers for more comments. The timeline for the last supplier of Commercial AC Chillers to switch to HFCs is a well guarded secret, however it is reasonable to assume that it will occur in the next 5 to 10 years rather than leaving it until 2020, the deadline of the US Clean Air Act.
HCFC-22	2006 Actual	zero in 2020	2006 Actual	zero in 2015	It is thought to be very optimistic to assume that consumption could be zero in 2015 as has been assumed in the lower limit projection, particularly if pre-charged imports and local OEM manufacturers using R22 are allowed to continue beyond 2010. The much more likely scenario is the middle to upper limit projections.

In the case of HCFC 123 and HCFC 124, projections were not made past 2017. The trend line indicated that these gases were likely to have ceased being imported and consumed by that time.

Similarly for HCFC 141b and HCFC 142b, the projections indicate that near to zero consumption would be achieved sometime around 2015. However, in reality there is some risk of a longer and relatively intransigent tail of demand for HCFC 141b and HCFC 142b dependent on how fast prices rise in coming years (as the reducing cap increases pressure on all HCFC supplies), how fast manufacturers of rigid foam insulations react to price rises and the level of recent or planned investment (capital inertia) in plant and equipment in the industries that requires these gases.

Projections from the trend line for demand for HCFC 22 clearly indicates a continuing requirement out to at least 2018 and more likely to beyond 2020.

6.2. Projection Method 2: Bottom Up

This method combined a detailed bottom up assessment of demand for HCFC 22, and employs the estimates for the other gases generated from the trend charting used in Method 1.

HCFC 22 is the gas which comprises approximately 85% of annual imports by volume, and around 98% of the HCFC gas bank, based on the starting point of the 2006 estimates of the installed base of equipment and the resulting servicing demands for gas.

To arrive at the estimates of future demands for HCFC 22, a number of assumptions are applied to the equipment population and types to project values for the service demand at 2010, 2015 and 2020. These assumptions include:

- Leak rates;
- Retirement rates of equipment over time;
- Timing of the end of imports of HCFC 22 pre-charged equipment as a result of international policy and manufacturers decision to end reliance on HCFCs; and
- Changes to OEM activity in Australia including manufacturers of rigid foam insulation.

As this is a business as usual projection, these assumptions do not include any estimates of the impact of policy changes or significant technological improvement such as the development of cheaper and effective 'drop in' replacement gases. Nor can it incorporate any effects of expected price rises, either modest or more dramatic increases (as one would expect to be brought about by significant shortfalls of supply to meet demand).

It was considered valid to use both methods. On the one hand, the observed changes in import levels during the last 10 years represent what has been possible under a business as usual scenario, even though those changes are the result of industry initiatives in close co-operation with and support of government policy to date.

On the other hand, the bottom up approach provides a robust estimate of actual gas demand to supply the installed base of equipment, much of which has been installed in the last decade. This is not to say that the expected demand will be met. However in the absence of any obstacles to supply, the (reducing but still significant) volumes projected as required using the bottom up approach are thought to be very realistic.

6.3. The Results

This study estimated that the total bank of HCFCs in operating equipment in Australia was at least 11,000[12] metric tonnes, nearly 98% of which is HCFC 22, distributed as follows:

- Residential and light commercial AC ~6,953 tonnes
- Commercial AC ~2,488 tonnes
- Small and medium commercial refrigeration ~555 tonnes
- Supermarket industry systems ~202 tonnes
- Cold storage and process refrigeration ~576 tonnes.

Additional to the applications listed above, of the 11,000 tonne lower estimate, there is approximately 232 tonnes of HCFC 123 employed in large commercial chillers, primarily centrifugal chillers.

HCFC consumption in Australia in 2006 was estimated as 2,131 tonnes. This total consumption figure is the total of all imports for the year, including imports of gas for use in manufacture of rigid foam insulation material, net of material that was then exported again. This 'top down' number was tested against a bottom up calculation and the volumes were found to reconcile well.

In the bottom up approach, consumption figures for each of the major application groups were estimated based on widely agreed annual leak rates for various applications, and tested in discussion with industry. Total consumption for each application area is based on estimates of gas consumed in the servicing of installed equipment (maintaining the gas bank) plus gas consumed by OEMs in manufacture or to charge new equipment in the field.

Taking this approach, of the 2,131 metric tonnes of recorded net imports for 2006, the end uses of 1,663 tonnes of HCFCs consumed were able to be identified as follows:

- Residential and light commercial AC ~827 tonnes
- Commercial AC ~305 tonnes

[12] An estimate refined in the 2008 ODS and SGG Inventory to be 11,280 metric tonnes in 2006.

- Small and medium commercial refrigeration ~98 tonnes
- Supermarket industry/systems ~47 tonnes
- Cold storage and process refrigeration ~70 tonnes

Both methods indicate that there is a real possibility of industry requiring significantly more HCFC than the allowed cap by as early as 2010.

Table 22. Forecasts of ODP Consumption Demand to 2020 (ODP tonnes)

Method 1	2006	2010	2015	2020
ODP Cap	130	70	10	2.5
Upper Limit est.	129.54	88.14	36.4	
Lower Limit est.	129.54	65.58	0.24	
Method 2				
ODP Cap	130	70	10	2.5
Upper Limit est.	128.90	115.03	51.75	12.39
Lower Limit est.	128.90	98.77	32.17	5.15

This unexpected result can be largely attributed to the surge in imports of split air-conditioning systems since 2002. Working gas in systems that would be considered as 'domestic' equipment made up nearly 60% of the HCFC gas bank in 2006.

This extremely rapid and unforeseen growth in the installed base of HCFC charged equipment was also the main reason for the original estimates of the HCFC gas bank projected in 2002 in the Burnbank report to be approximately half of the estimate of the gas bank now.

It should be noted that while the cap on bulk imports begins a steady reduction from next year, presently there is every indication that the HCFC gas bank will continue to expand for some years yet, on the back of the existing trend for larger numbers of ever cheaper air-conditioning systems.

In consultation with industry, it was suggested that the next cap reduction in 2008, to 100 ODP tonnes per year, is likely to start putting upward pressure on prices. If any of the three higher projections are realised then the potential is for price rises to be very high.

Rapid price rises will have a number of predictable outcomes in the industry including:

- Increased recovery and reuse of gas 'in the field';
- Attempts to substitute cheaper working gases where ever possible (although it must be noted that industry suggests many smaller devices will increase leak rates and operate very inefficiently if they are specified for HCFC 22 and are then gassed with a replacement;
- Substitution of alternative foam blowing agents as rapidly as possible; and
- Imports of recycled HCFC 22 from international suppliers.

The following figures, extracted from the report '*HCFCs in Australia – Projections of Future Demand*'(August 2007), illustrate projections for each of the HCFC species imported and the aggregated projections created via the two different methods.

Figure 1 - HCFC-22 Forecast

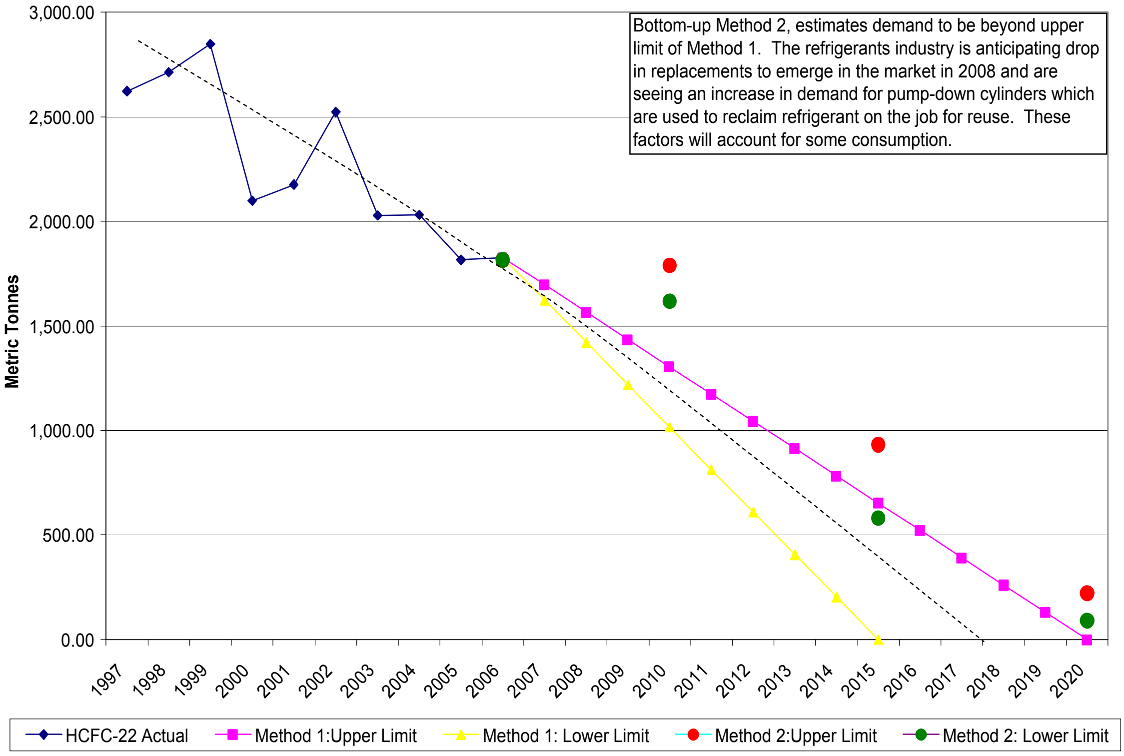


Figure 2 - HCFC-123 Forecast

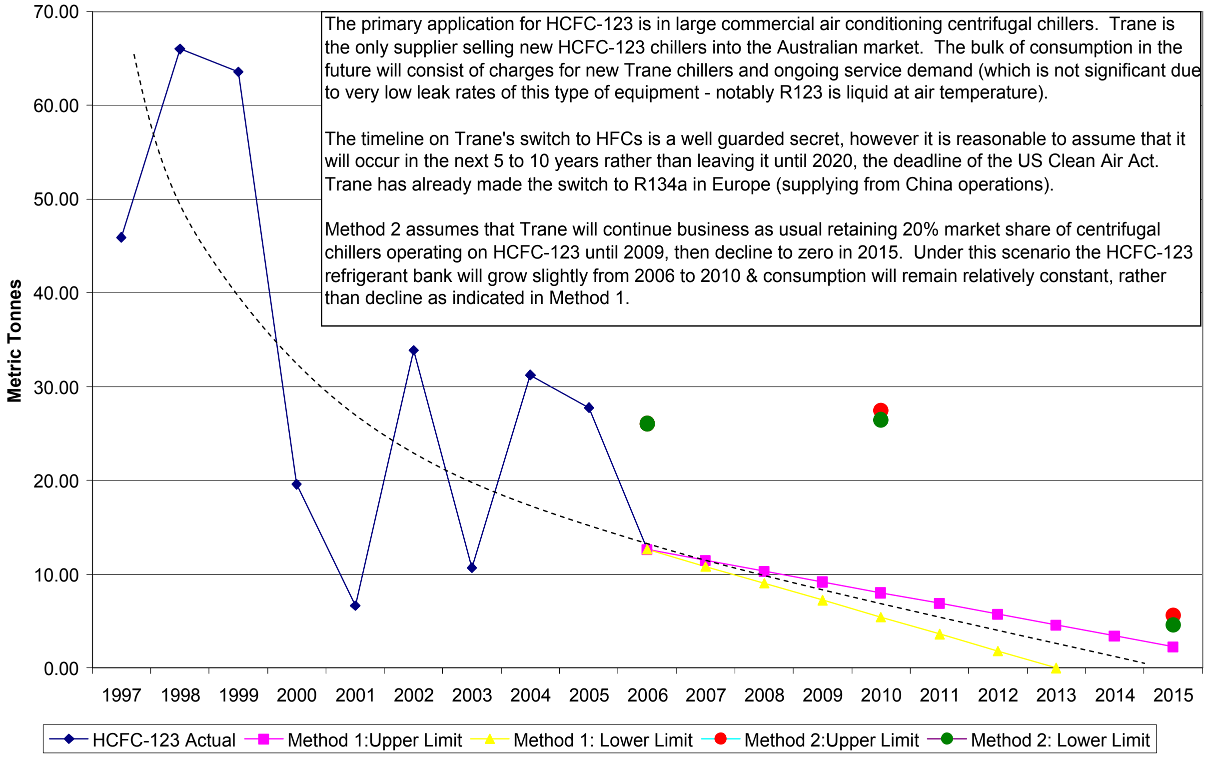
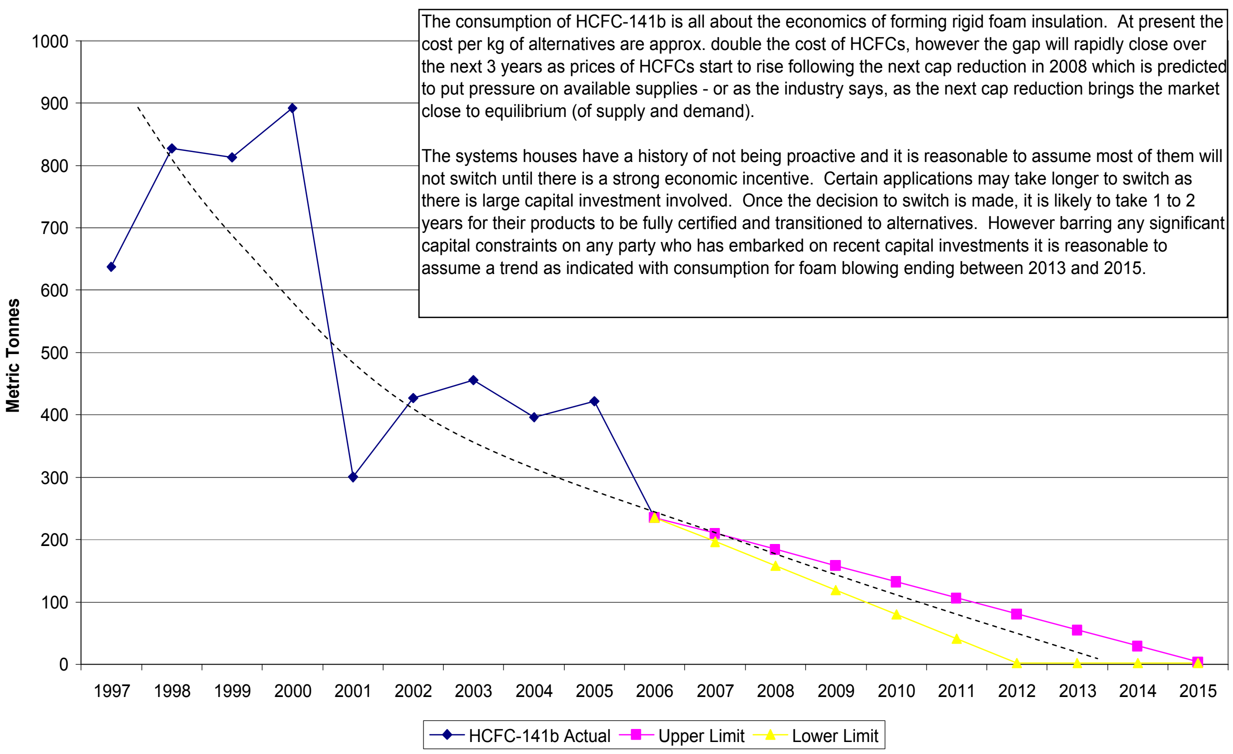


Figure 3 - Foam Industry: HCFC-141b Forecast



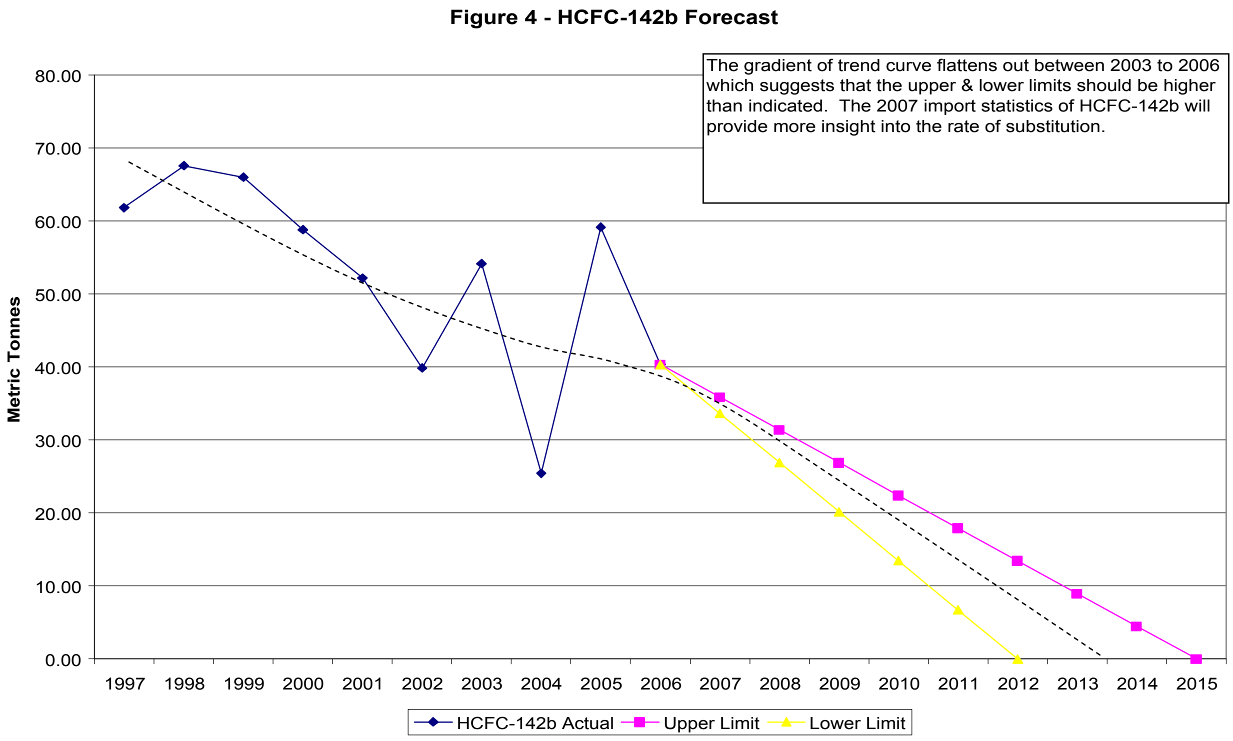


Figure 4 - HCFC-142b Forecast
The gradient of trend curve flattens out between 2003 to 2006 which suggests that the upper & lower limits should be higher than indicated. The 2007 import statistics of HCFC-142b will provide more insight into the rate of substitution.
Metric Tonnes
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
HCFC-142b Actual
Upper Limit
Lower Limit

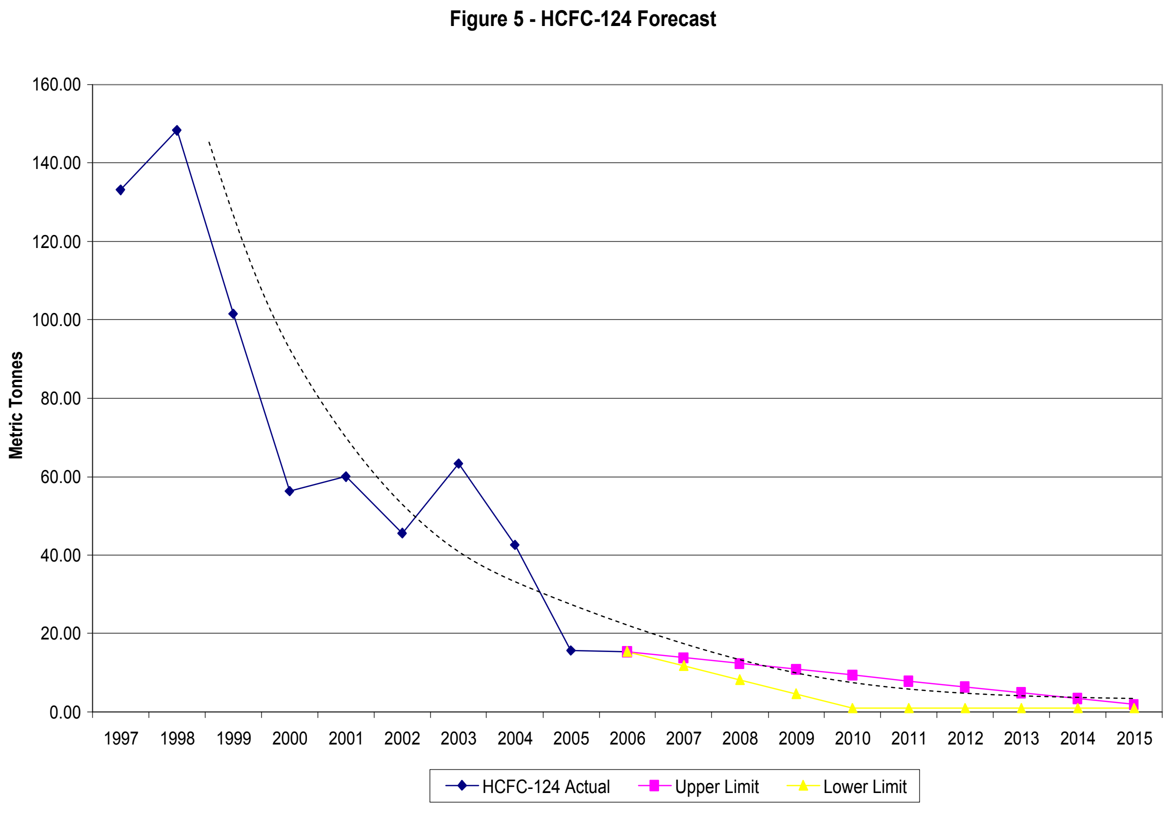


Figure 5 - HCFC-124 Forecast
Metric Tonnes
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
HCFC-124 Actual
Upper Limit
Lower Limit

Figure 6 - Method 1: Consumption Projection

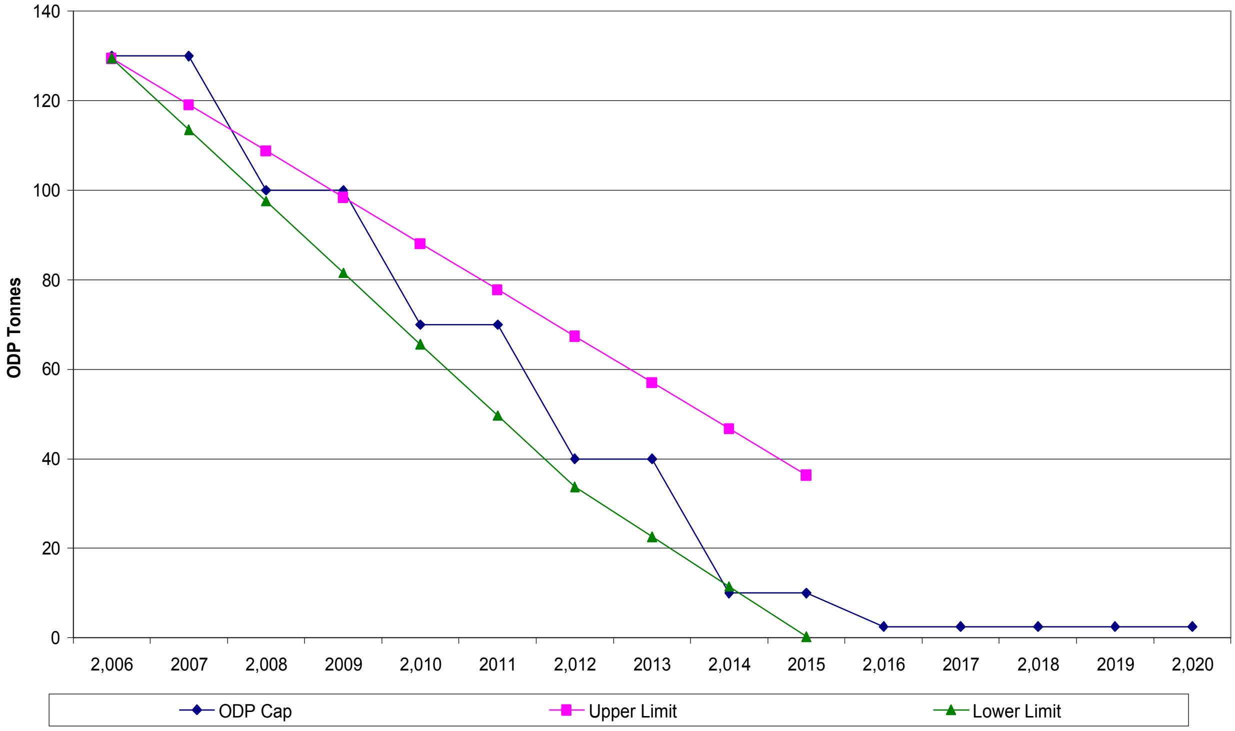
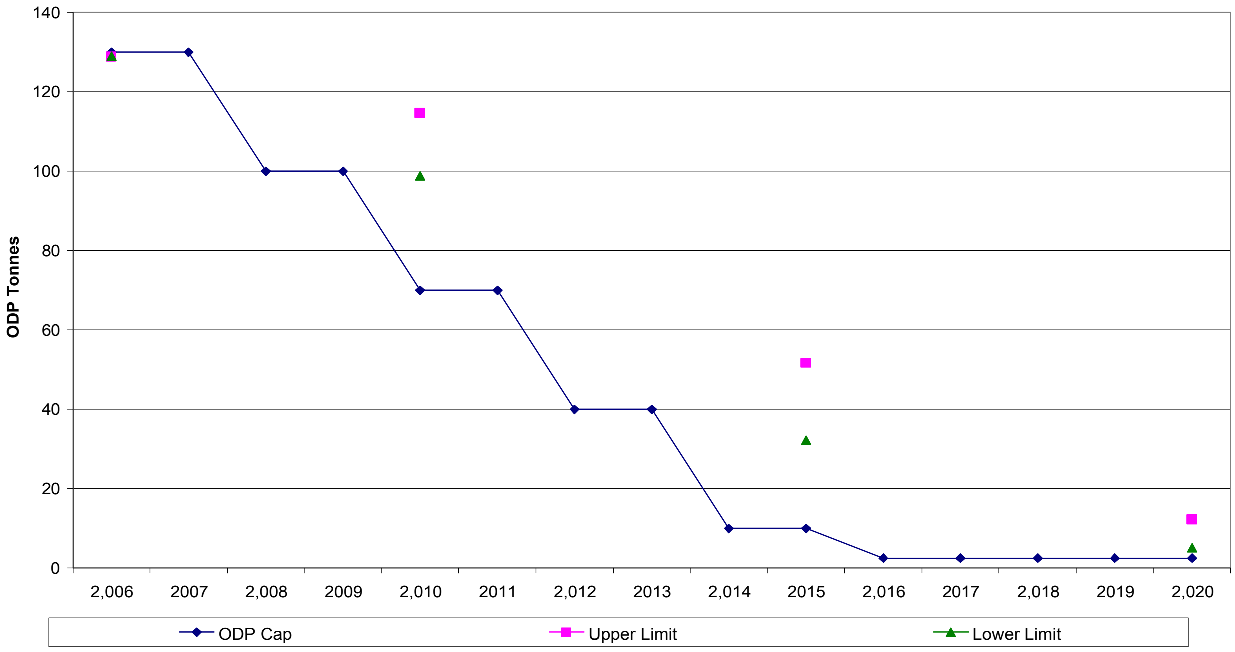


Figure 7 - Method 2: Consumption Projection



Appendix 1 – Substances, industry Sectors and applications

SUBSTANCES

- ***Hydrochlorofluorocarbons (HCFCs)***
- ***Hydrofluorocarbons (HFCs)***
- ***Perfluorocarbons (PFCs)***

INDUSTRY SECTORS AND APPLICATIONS

- ***Residential and light commercial air conditioning sector***
  - Split systems
  - Wall hung split systems
  - Window/wall units
  - Refrigerated portable
- ***Commercial air conditioning sector***
  - Chillers
  - RT packaged
  - Precision control A/C
  - VRV systems
- ***Mobile air conditioning sector***
  - Passenger compartments of light duty vehicles cars & trucks
  - Passenger compartments of buses & trains
- ***Water heating heat pumps sector***
  - Domestic
  - Commercial systems

- ***Domestic refrigeration sector (household refrigerators and freezer)***
- ***Commercial refrigeration sector (retail display)***
    - Supermarket systems (small medium and large)
    - Stand alone equipment
        - Self-contained display cases
        - Glass door merchandisers
        - Reach in refrigerators
        - Reach in freezers
        - Ice making equipment
        - Refrigerated vending machines
        - Ice cream displays
        - Cold water dispensers
        - Ice bins
- ***Food processing, cold storage and industrial refrigeration sector***
    - Chillers for food processing and industrial applications
    - Cool rooms and cold storage
- ***Transport refrigeration sector***
    - Trailer & inter-modal refrigeration
    - Diesel drive truck refrigeration
    - Off engine/vehicle powered refrigeration (option electrical stand-by)
- ***Foam sector***
    - Commercial refrigeration
    - Refrigerated transport
    - Water heaters
    - Spray foam
    - Block foams
    - Other foam applications

- ***Fire protection sector***
  - Fixed systems
  - Portable systems
- ***Aerosols, solvents, electronics and other uses sector***
  - Medical aerosols
  - Technical aerosols (including dusters, freeze sprays, flux removers, mould release agents and, electronic contact cleaners)
  - Safety aerosols (including tyre inflators, safety signal horns and insecticides for planes and restricted areas)
  - Consumer and novelty aerosols (including silly string, wine cork removers, spray snow and noise makers)
  - Electronics etching processes (PFCs)
  - Solvent uses (including metal cleaning, electronics cleaning, precision cleaning, drying and carrier solvents)
  - Other uses

Appendix 2 – Leak Rates

The issue of 'leak' rates used to calculate ODS and SGGs contained in the retiring stock of equipment is an area that is recommended for further refinement. There are a range of leak rates accepted as reasonable by various authorities and experts, however leak rates vary considerably for various types of equipment, and, within those types of equipment, vary relative to different gas charges that they may hold. The differing working gases are contained in systems with differing engineering standards, seals and systems.

While some global consensus has been reached on acceptable leak rates for mobile air-conditioning, there is still significant uncertainty about leak rates from some very large populations of equipment, such as small stationary air-conditioning, commercial self-contained refrigeration, supermarket systems and the cold chain for instance.

As well as settling on an appropriate leak rate, decisions have to be made regarding emissions at installation, theoretically a once off event in the life of some of the largest classes of equipment such as small stationary air-conditioning systems. On the other hand, very hard working systems, such as supermarket systems, are more likely to have large losses to air as a result of equipment breakdown, hose or seal ruptures and service errors.

Leak rates used internationally and those that had been previously used in Australia were reviewed. Recent industry studies were reviewed and industry informants were questioned. Considering the issues and available information, and with expert advice from manufacturers, service agents and engineers on particular equipment types, decisions were made across all classes and types of equipment to apply expected leak rates to the working bank and establish an estimate for total annual losses to air of working gas.

Emissions from Passenger Vehicles had two components; the leak rate of typically 9% plus an allowance of 5% for crash and repairs.

Equipment Type	Average Charge Size (kg)	Leak Rate HCFCs (%)	Leak Rate HFCs (%)
Residential & Light Com AC			
Wall Hung Split Systems	1.7	10.0%	3.0%
Split Systems	4.7	11.9%	3.0%
Window/Wall Units	0.84	1.3%	1.0%
Portable	0.56	1.3%	1.0%
Commercial AC			
RT Packaged	12.2	10.0%	7.0%
Chillers < 530 kW	115	8.3%	5.0%
Chillers > 530 & < 1055 kW	240	8.3%	5.0%
Chillers > 530 & < 1055 kW (HCFC-123)	240	1.0%	-

Chillers > 1055 kW	634	8.3%	5.0%
Chillers > 1055 kW (HCFC-123)	765	1.0%	-
VRV Systems	8	-	7.0%
Precision Control AC	30	11.9%	10.0%
Other Heatpump Applications			
Solar Hot Water	0.6	-	3.0%
Supermarket Industry/Systems			
Small	130	30%	15%
Medium	500	23%	15%
Large	900	21%	15%
Small & Medium Commercial Refrig.			
Self Contained & Small Com Refrig	2.7	5%	2%
Clubs, Pubs, Hotels & Liquor Retailing	13.4	15%	10%
Catering & Hospitality		15%	10%
Retail Food		15%	10%
Cool Rooms (Primary Industry)		15%	10%
Milk Vat (Primary Dairy) Industry	40	20%	15%
Domestic Refrig with R22	0.89	2%	-
Cold Storage & Process Refrig			
Cold Storage	-	20%	-
Food Chain, Industrial & Other			
Small Chillers	16	8.3%	7.0%
Medium Chillers	115	8.3%	7.0%
Large Chillers	356	8.3%	7.0%
Vehicles			
Passenger Vehicles	0.6		9%
Light Commercial Vehicles	0.65		9%
Rigid Trucks: Light	0.65		9%
Rigid Trucks: Heavy	1.0		9%
Articulated Trucks	1.0		9%
Non Freight Trucks	0.65		9%
Commuter Vehicles/Buses	1.0		9%
Buses (>7m in length)	9.0		12.5%
Passenger Rail	6.9		9%
Locomotive	2.0		9%
Off Road - Industrial/Mining/Agriculture	2.5		12.5%
Defense (Land/Air)	4.0		9%
Transport Refrigeration			
Truck: Trailer & Inter-Modal	10	30%	15%
Truck: Diesel Drive: Truck	7	30%	15%