

CLIMATE CHANGE AND SUSTAINABILITY SERVICES

End-of-Life Domestic Refrigeration and Air Conditioning Equipment in Australia

Department of the Environment

23 July 2014

ADVISORY

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The findings in this report are based on a qualitative study and the reported results reflect a perception of the domestic refrigeration and air conditioning (RAC) industry in Australia but only to the extent of the sample surveyed, being the references tabled and discussions with industry stakeholders. Any projection to the wider RAC industry is subject to the level of bias in the method of sample selection.

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Executive summary

A study was carried out to map the disposal of domestic refrigeration and air conditioning ('RAC') equipment at end-of-life in Australia. The purpose of the study was to understand the disposal pathways, key stakeholders, and the influencing factors such as legislation, costs, and technology.

There appears to be a high rate of recovery of RAC equipment for metals recycling, and a high rate of recovery of refrigerant gases from air conditioners, but a low rate of recovery of refrigerant gases from domestic refrigerators and freezers at end-of-life.

Domestic Context

The main factors affecting disposal pathways and stakeholder behaviour are:

- Federal Government policy initiatives in the areas of waste, ozone depleting substances, and synthetic greenhouse gases
- State Government initiatives such as the New South Wales "Fridge Buyback Scheme"
- Local Government practices and initiatives around landfill diversion as well as collection and disposal of RAC equipment
- Financial factors including scrap metal prices in world markets (which are promoting a high rate of recovery of RAC equipment), supply chain costs, and waste disposal levies.

The major stakeholders identified in the RAC disposal chain are:

- Retailers who "take back" refrigerators and freezers as a sales "add on" service
- Local Government Authorities (LGAs), who are responsible for hard rubbish collection including degassing and disposal of refrigerators and freezers
- Servicing personnel who remove air conditioning units as part of a new installation
- Metal recyclers (shredders) who separate RAC equipment into metals and plastic.

Disposal Pathways and Quantities

The main controlled disposal pathways for refrigerators and freezers are:

- Via kerbside collection by LGAs (or their contractors), "drop off" and consolidation at waste transfer stations or landfills, and transfer to metal recyclers for shredding
- Via "take back" schemes operated by retailers who degas the equipment before sending it to metal recyclers for shredding.

A significant contribution to the refrigerator disposal chain is the activities of "scavenger" parties who collect from the kerbside and from other points in the disposal chain and sell directly to recyclers. This uncontrolled disposal is a significant source of non-compliance to the regulations around collection and disposal of refrigerant gases. Other sources of refrigerant gas loss are from LGAs where they are not degassing, metal recyclers where they do not check RAC equipment for refrigerant gas prior to shredding, and from damage to RAC equipment in the disposal chain.

By comparison, the disposal pathway for air conditioners is more highly regulated compared to that for refrigerators. A licensed service technician is generally involved in installation and will collect and consolidate the recovered refrigerant from the obsolete unit.

RAC sales experienced a high rate of growth between 2000 and 2006. This was due to the popularity of two-door fridge and freezer units, and of split system air conditioners. This is predicted to lead to an increase in the annual disposal rates from 800,000 to 1.2 million units (refrigerators and freezers) and from 600,000 to 1 million (air conditioners) by 2024.

The increased use of split systems and increased availability from discount and online retailers may lead to uncontrolled disposal and losses of refrigerant gases to the environment due to the reduced incentive to use licensed technicians in installation and removal of old appliances.

Material Composition

Disposal of RAC generates about 56,600 tonnes of ferrous waste and 14,000 tonnes of non-ferrous waste (current levels); and up to 33,000 tonnes of floc to landfill. Disposal also generates smaller quantities of other metals, which are contained in non-ferrous waste.

RAC equipment also contains a variety of plastics types including ABS, PVC, polystyrene and insulating polyurethane foams. The recycling rate of plastics in RAC equipment is small, due to the practice of RAC equipment being shredded with other materials, which leads to contamination and reduction in the grade of the non-metallic output (floc). There are no significant exports of shredded plastic waste or floc, as they have no saleable value. All shredder floc is currently disposed of to landfill. Shredding of polyurethane foam will release blowing agents into the atmosphere, including fluorinated compounds in older appliances.

Stockpiling of refrigerant gas and use of recovered refrigerant gas to fill appliances has occurred following the introduction of the carbon-pricing mechanism (CPM). This is due to the impact of the carbon price on refrigerants with high global warming potential, and is expected to disappear with the repeal of the CPM.

Other materials that need to be considered in the end-of-life treatment of RAC equipment include:

- Trace metals such as mercury, lead and cadmium that are present in electronic components including printed circuit boards, switches and lighting
- Brominated compounds used as flame-retardants
- Polychlorinated biphenyls (PCBs) used in capacitors and transformers
- Oil from compressors, and
- Glass

Based on the current (2014) disposal rate of RAC refrigerators and freezers, and industry data for the composition of these appliances; the rate of entry of trace metals into the disposal chain is approximately 1 tonne (mercury), 100 tonnes (lead) and 8 tonnes (cadmium) per annum. No reliable data was able to be obtained for air conditioning equipment. Brominated flame retardants and PCBs are not present in modern appliances in any significant quantities.

Oil from compressors is largely not recovered in RAC equipment disposal in Australia.

Industry Dynamics and Opportunities

A very high proportion of the metal composition of RAC equipment in Australia is processed through shredding operations, and is ultimately recycled through local and overseas steelmaking, and overseas non-ferrous metal smelting. This is driven by the value obtained for scrap metal in local and overseas markets. There is minimum disassembly for “value adding” in Australia.

Increased value could be extracted from the RAC disposal chain by the use of dedicated recycling and shredding facilities to improve the opportunity to recover plastics of saleable value. Improvements to the recovery of refrigerant gas from the disposal chain could be made by:

- Enforcement of current regulations (with LGAs and the service sector) and by the use of controlled collection to limit the opportunities for collection by scavengers (i.e. where the LGA is contacted to remove an item of RAC equipment at a particular time, rather than having it just left at the kerbside)
- Encouraging the uptake of “take back” schemes by retailers and greater overall publicity of the need to recycle and recover RAC equipment

Controlled atmosphere shredding could be used to recover refrigerant gases and blowing agents, however this may not be cost effective.

The most comprehensive scheme of product stewardship of RAC equipment at end-of-life exists in the European Union (EU). The onus is on producers (and importers) of equipment to fund and provide facilities for collection, degassing, and disposal. Recyclers must achieve minimum recovery rates. The main benefits of this approach relative to Australian practice are that there is a higher rate of recovery of refrigerant gases and of plastics of saleable value.

The main disposal pathways for RAC equipment are represented in Figure 1 and Figure 2 that follows.

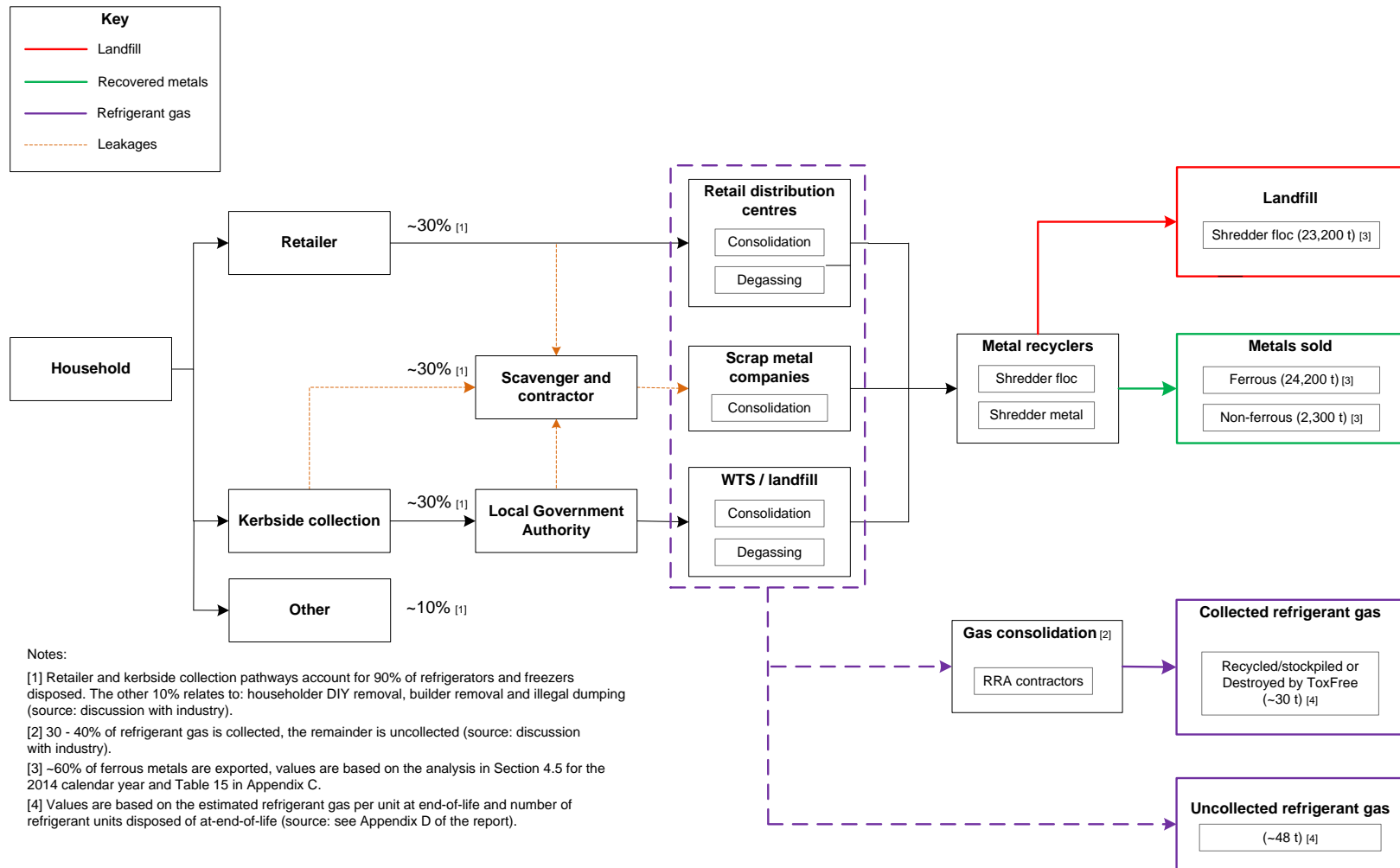


Figure 1: The most significant end-of-life disposal pathway for refrigerators, source: discussions with industry stakeholders and Appendix B

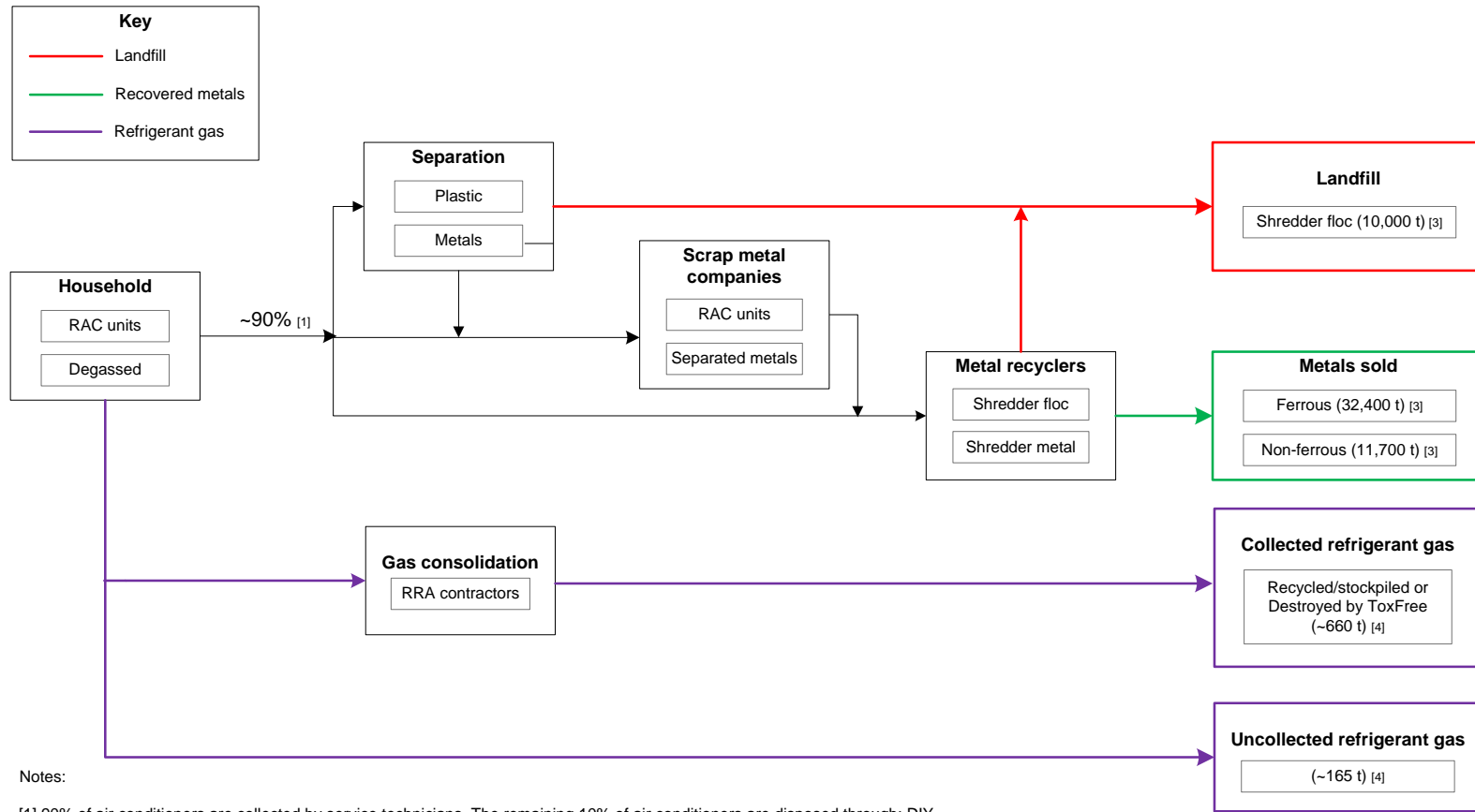


Figure 2: The most significant end-of-life disposal pathway for air conditioners, source: discussions with industry stakeholders and Appendix B

Glossary of terms

| Term | Description |
|-------------------|---|
| ABS | Acrylonitrile is a chemical compound used in the manufacture of plastics such as polyvinyl chloride. See 'PVC'. |
| BSL | The Brotherhood of St Lawrence |
| CFC | Chlorofluorocarbons. See 'ODS' |
| CPM | Carbon Pricing Mechanism. A legislative program introduced by the Australian Government in 2011 to impose a financial liability on large polluters of carbon dioxide |
| Disposal pathways | Describes different processes for disposing of whitegoods, each with different characteristics such as different tasks or actors |
| Domestic RAC | Refrigeration and air conditioning equipment used in a household or dwelling, as outlined at Section 1.2 |
| E3 | Equipment Energy Efficiency Program. A joint initiative of the Australian and New Zealand Governments to improve the energy efficiency of appliances and products to generate economic and environmental benefits |
| EERA | European Electronics Recycling Association |
| EPA | Environmental Protection Agency |
| EOL | End-of-Life. A term applied to whitegoods indicating that a product is at the end of its useful life |
| Ferrous metals | Any metal, including alloys, with appreciable iron content (e.g. steel) |
| GEMS | Greenhouse and Energy Minimum Standards. Legislation introduced by the Australian Government in 2012 to create a national framework for appliance and energy efficiency in Australia |
| GWP | Global Warming Potential. A multiplier indicating the potential of a chemical to contribute to the greenhouse effect, relative to the greenhouse effect of carbon dioxide |
| HCFC | Hydrochlorofluorocarbons. See 'ODS' |
| HFC | Hydrofluorocarbons. See 'SGG'. |

| Term | Description |
|---------------------|---|
| HVAC | Heating, Ventilation and Air Conditioning. Refers to systems, often in a commercial or industrial context, that are installed in buildings for the purpose of controlling the thermal environment |
| Kerbside collection | Service provided, often by municipal or local authorities, to collect waste from households for the purpose of disposal. Also known as hard rubbish or verge collection |
| LGA | Local Government Authorities, commonly referred to as Councils |
| MEPS | Minimum Energy Performance Standard. Legislative requirements that specifies the minimum level of energy performance of whitegoods and other domestic appliances in Australia and New Zealand |
| MRF | Materials Recovery Facility. A specialised plant that receives, separates and prepares recyclable materials for marketing to end-use manufacturers |
| NARTA | The National Associated Retail Traders of Australia is an independent electrical buying group in Australasia |
| Non-ferrous metals | Any metal, including alloys, that do not contain appreciable amounts of iron |
| ODS | Ozone-Depleting Substances. Chemicals which, when emitted into the atmosphere, cause the depletion of the ozone layer. Includes chlorofluorocarbons (CFCs), and hydrochlorofluorocarbons (HCFCs) |
| Product stewardship | An approach to reducing the environmental and other impacts of products by encouraging or requiring manufacturers, importers, distributors and other persons in the product chain to take responsibility for those products |
| PCB | Polychlorinated biphenyl is a synthetic organic chemical compound made from chlorinated hydrocarbons that has been used in capacitors and transformers |
| PVC | Polyvinyl chloride is a commonly produced plastic, classified as a thermosetting resin |
| RAC | Refrigeration and Air Conditioning equipment, including freezers |

| Term | Description |
|---------------|---|
| RAD | Responsible Appliance Disposal (RAD) is a voluntary partnership program introduced by the US Environmental Protection Agency to recover metals, refrigerant gases and other materials from whitegoods |
| Refrigerant | A substance used in a refrigeration cycle which undergoes phase transitions from a liquid to a gas and back again in order to transfer heat |
| Refrigeration | Process in which work is done to move heat from one location to another. Where the term refers to equipment it includes both refrigerators and freezers |
| RRA | Refrigerant Reclaim Australia. The product stewardship organisation for the Australian refrigerant industry |
| SGG | Synthetic Greenhouse Gases. Man-made chemicals which contribute to the greenhouse effect. Includes hydrofluorocarbons (HFCs) |
| Shredder | A machine to reduce the size of materials by cutting them using an automated process |
| Shredder floc | Waste residue remaining after the shredding of vehicles, whitegoods or other appliances. Often largely comprised of plastics and rubber |
| VEET | Victorian Energy Efficiency Target, a Victorian Government scheme established in 2009 to reduce greenhouse gas emissions through the implementation of a market for energy efficiency |
| Whitegoods | Machines which accomplish a routine housekeeping task in a domestic context. Includes refrigerators, freezers and air conditioners as well as ovens, stovetops, toasters, washing machines, etc |
| WTS | Waste Transfer Station is a temporary consolidation point for collected waste |

| Term | Description |
|-------------|---|
| WEEE | Waste Electrical and Electronic Equipment (WEEE) Directive. A product stewardship scheme introduced in the European Union in 2002 to facilitate the management of waste from electrical and electronic goods sold in the EU |
| WEEE II | An updated version of WEEE introduced into the EU in 2012 (also known as the Recast WEEE Directive) |

1. Background

1.1 Background on the Project

The Department of the Environment (the 'Department') has commenced a project to explore the feasibility of a product stewardship approach for end-of-life domestic refrigeration and air conditioning (RAC) equipment. The Department has engaged with stakeholders to consider the need, feasibility, and possible options for future product stewardship approaches. For a list of the stakeholders engaged and the method of engagement see Appendix A.

The Department has identified the primary stakeholders to be consulted during the feasibility study which included associations and industry groups representing:

- RAC equipment manufacturers and retailers
- RAC equipment servicing industry
- Ozone depleting substances (ODS) and/or synthetic greenhouse gases (SGG) destruction and reclamation industry
- E-waste recycling industry
- Waste industry
- Scrap metal and recycling industries
- Non-government organisations
- Building, construction and demolition industry
- Trade Skills Councils
- Federal, State and Territory and local Governments.

The aim of the feasibility study is to provide the Government with advice on the potential of a product stewardship approach for domestic RAC equipment with small refrigerant charges. The study will consider the recovery of:

- Refrigerant gases
- Metals
- Plastics
- Other materials for reuse or appropriate disposal such as glass, rubber, oil, mercury, lead, zinc, beryllium, cadmium, nickel and magnesium, polychlorinated biphenyls, hexavalent chromium, bromine, and antimony.

Product stewardship is an approach to managing the impacts of different products and materials. It acknowledges that those involved in producing, selling, using, and disposing of products have a shared responsibility to ensure that those products or materials are managed in a way that reduces their impact on the environment, human health and safety throughout their lifecycle.

The overall project will examine the feasibility of a product stewardship approach for domestic RAC equipment under the *Product Stewardship Act 2011* (the Act). The costs and benefits to industry, Government, and the community of implementing an approach under the Act will be assessed. The cost and benefit of different approaches will be considered, such as a voluntary industry approach, co-regulatory model, or a regulatory model. To inform this process the Department has undertaken this study to map the disposal of domestic RAC equipment at end-of-life in Australia.

Australia currently has a national product stewardship scheme for management and disposal of refrigerant gases and unwanted ODS and SGGs. This scheme is run by Refrigerant Reclaim Australia and operates through the established refrigerant wholesaler network. The overall aim of the project is to look at the feasibility of a product stewardship approach to manage the whole product at end-of-life, including all materials such as any plastic and foam.

1.2 Overview of domestic RAC equipment

Domestic RAC equipment is considered to include refrigerators, freezers, and air conditioners with small refrigerant charges that are designed primarily for use in domestic settings.

Domestic RAC equipment comprises:

- Refrigerators (comprising upright refrigerators, bar refrigerators, and wine refrigerators)
- Freezers (comprising chest freezers, upright freezers, and bar freezers)
- Air conditioners (comprising portable home air conditioners, split air conditioners, window air conditioners, evaporative coolers, and ducted air conditioning systems).

Within these categories there are a range of manufacturers, models, and sizes.

Domestic RAC equipment can contain a range of materials including refrigerants which can be ODS, SGG, or alternative refrigerants such as ammonia, carbon dioxide, and hydrocarbons. It can also contain ferrous metals, non-ferrous metals (mercury, lead, zinc, beryllium, cadmium, nickel and magnesium), plastic, rubber, glass, oil, polychlorinated biphenyls, hexavalent chromium, bromine and antimony.

These materials can require specialist waste disposal or recycling methods to ensure sound management at end-of-life and may be subject to different control measures.

1.3 Domestic RAC equipment as waste in Australia

In 2012 there was a stock of approximately 28 million units of domestic RAC equipment in Australia and approximately 1.3 million of these units reached end-of-life in 2012 (including light commercial and chiller-type air conditioners) (Expert Group, 2013). There is little published information about the disposal pathways for end-of-life domestic RAC equipment in Australia and treatment may differ across state and territory jurisdictions, as well as local government areas. End-of-life domestic RAC equipment may be disassembled or shredded before disposal or recycling. This reduces the overall volume of the waste equipment so that it can be more readily transported and enable valuable materials such as metals to be separated and sold.

Some end-of-life domestic RAC equipment, or components of the equipment, may be disposed of directly into landfills with little or no treatment. However, several Australian states have landfill bans in place on a range of waste items, such as whitegoods.

Ideally, the first treatment that should be applied to end-of-life domestic RAC equipment is the removal of the ODS or SGG refrigerant gas charge. Most domestic air conditioners and refrigerators use ODS and SGGs, such as hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs), as the refrigerant, although older models which contain chlorofluorocarbons (CFCs) are still entering the waste stream.

In Australia it is an offence to deliberately emit an ODS or SGG, unless it is in accordance with the Ozone Protection and Synthetic Greenhouse Gas Management Regulations 1995 (the Regulations).

Possible disposal pathways for end-of-life RAC equipment in Australia

The common understanding within industry is that ultimately domestic RAC equipment is recycled, sent to landfill, or illegally dumped; with the equipment handled or processed by a range of different groups along the supply chain including:

- State, Territory, or Local Government run waste disposal centres (e.g. Waste Transfer Stations (WTS) and landfill operators)
- Second hand dealers (such as resellers and charity groups)
- Scrap metal merchants
- Kerbside collection services – including schemes such as Fridge Buyback operating in New South Wales, which purchases old end-of-life refrigerators or bulky goods collection
- Materials Recovery Facility (MRF): a specialised facility that receives, separates, and prepares recyclable materials for marketing to end-user manufacturers. A MRF may also be referred to as municipal/mixed recycling or recovery facility, and usually involves mechanical sorting and separation of materials.

1.4 Engagement overview

Aims and scope

The aim of this study was to provide the Department with a robust and accurate data analysis and understanding of the flow and market share dynamics of domestic RAC equipment that is at end-of-life in Australia. This will inform the Department's overall project, which is to examine the feasibility of a product stewardship approach for domestic RAC equipment under the *Product Stewardship Act 2011* (the Act). The scope of work of this study covered:

- Identifying the stakeholders that participate in the RAC equipment disposal chain
- Identifying the factors that influence their behaviour and actions in the disposal chain
- Mapping the significant disposal pathways for RAC equipment
- Developing an understanding of the quantity of RAC items entering the disposal chain
- Reviewing overseas practices for managed disposal of RAC equipment.

Methodology

The methodology involved an analysis of stakeholders involved in the RAC disposal chain, the impact of stakeholders on disposal practices and the impact of other factors such as regulations and supply chain costs. It also included a quantitative assessment of the amounts of RAC items entering the disposal chain from 2014 to 2024. Data was gathered by way of:

- Research into the RAC equipment supply chain and the factors affecting sales, disposal rates, and choice of disposal pathway
- Extensive consultation with industry stakeholders in the retail, manufacturing, importing, regulation, and waste disposal sectors; via face-to-face meetings, telephone interviews and participation in a workshop held in Sydney on 3 March 2014 (refer to Appendix A)
- Analysis of sales and lifespan data to determine disposal rates from 2014 to 2024.

In addition, research was carried out and an interview conducted with the European Commission, Directorate General for the Environment, to identify the practices for disposing of RAC equipment in certain overseas jurisdictions where regulations were in place.

1.5 Report outline

The structure of this report is as follows:

- Section 2: Provides the domestic context for the disposal of RAC equipment, including:
 - legislation for Commonwealth, States, and Territories, and
 - the role of stakeholders and the factors influencing their behaviours
- Section 3: Provides a summary of RAC disposal, including:
 - disposal pathways
 - stock and disposal rates
 - waste composition
- Section 4: Provides a summary of RAC material composition at end-of-life, in terms of the outputs from the shredding process and the physical characteristics of the equipment
- Section 5: Presents the recycling industry dynamics, opportunities and constraints for recycling RAC equipment in a domestic and international context.

2 Domestic context

The key components of the domestic RAC supply chain are: supply, use, and disposal (see Figure 3). Generally, the householder determines the end the life of the RAC equipment because they are at the start of the disposal pathway. The householder will dispose of RAC equipment due to equipment failure or a desire for a model upgrade (i.e. behavioural attribute of the householder). The disposal pathway and treatment of the RAC equipment once it leaves the household is influenced by the policy framework and stakeholder behaviour.

A discussion about the policy framework and the role of stakeholders in the disposal of RAC equipment follows.

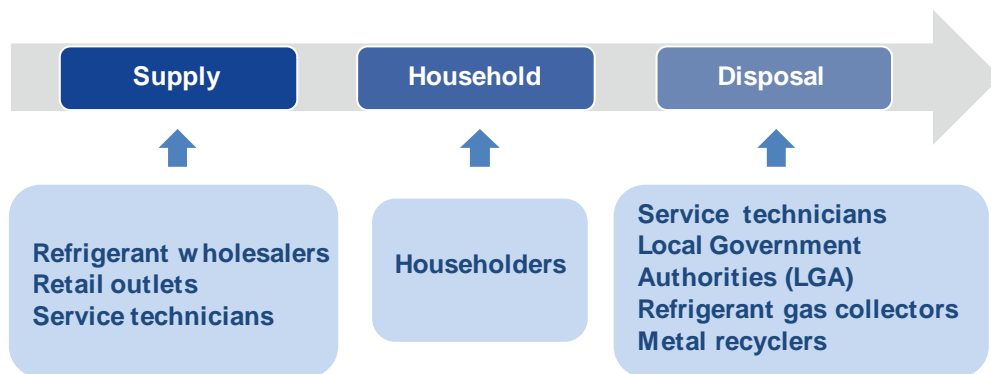


Figure 3: The key components of the domestic RAC supply chain, source: based on discussions with industry stakeholders

2.1 Federal Government policy framework

The Federal Government has legislation and policies that affects the end-of-life pathway and treatment of RAC equipment. These include:

- *National Waste Policy.* This sets Australia's waste management and resource recovery direction to 2020 (Commonwealth of Australia, 2009). The management of waste is primarily the responsibility of LGAs. The role of the Commonwealth Government is to ensure that international obligations are met (most notably the Kyoto and Montreal Protocols). This policy does not directly address the end-of-life of RAC equipment.
- *The Hazardous Waste (Regulation of Exports and Imports) Act 1989* regulates the export and import of hazardous waste to ensure safe disposal (Commonwealth of Australia, 1989). This policy does not directly influence the end-of-life of RAC equipment, especially as there are no significant exports of refrigeration equipment; however it is relevant to the *treatment of shredder waste if deemed to be hazardous.*
- *The Ozone Protection and Synthetic Greenhouse Gas Management Act 1989 and the Ozone Protection and Synthetic Greenhouse Gas Management Regulations 1995.* Under the ozone legislation it is an offence for ozone depleting substances and synthetic greenhouse refrigerant gases to be discharged where the activity is not in accordance with the Regulations (as stipulated under Section 45B of the Ozone Act). Together they impose penalties and obligations for the recovery of fluorocarbon refrigerant gases. A licence is required to handle refrigerant gases, including for their recovery.

These legislative instruments prohibit the discharge of refrigerants to atmosphere. RAC equipment must be degassed by a licensed technician. For spilt air conditioners this occurs when the system is removed from the household. For other RAC equipment, the risk occurs at several points along the disposal pathway; during transportation, disassembly, and before shredding.

Based on discussions with the various stakeholders, an overall recovery rate of 30 to 40% is indicated for refrigerant gases in domestic RAC equipment. This is represented in Table 1 below:

Table 1: Estimated refrigerant recovery rates for RAC equipment

| RAC collection pathway | Estimated percentage of RAC in pathway | Estimated refrigerant recovery rate | Overall Recovery |
|-------------------------|--|-------------------------------------|-------------------|
| Air conditioners | | | |
| Service technicians | ~90% | ~90% | ~80% |
| Other (e.g. scavengers) | 0% | 0% | 0% |
| Total | | | >80% |
| Refrigerators | | | |
| LGA | ~30% | ~50% | ~15% |
| Retailers | ~30% | ~50% to 70% | ~20% |
| Other (e.g. scavengers) | ~40% | 0% | 0% |
| Total | | | 30% to 40% |

The Australian Refrigeration Council (ARC) reports that there are approximately 60,000 licences in Australia. The licence types range from a basic refrigerant recovery licence, to more technically complex split air conditioning installation and removal licences, through to a full commercial servicing licence.

Other legislative instruments affecting the RAC disposal chain include:

- The *Product Stewardship Act 2011* There are currently no programs in place under this Act in relation to RAC equipment. However it is worth noting that the Product Stewardship Televisions and Computers program has been operating for over one year, and includes some waste materials similar to those found in RAC equipment
- The *Greenhouse and Energy Minimum Standards Act 2012* (GEMS Act) which is administered by the Department of Industry through the Equipment Energy Efficiency (E3) Program. The Greenhouse and Energy Minimum Standards (GEMS) sets out a nationally consistent approach for regulating the energy efficiency of equipment (GEMS Regulator, 2013). E3 is the overarching program under this Act for energy efficiency labelling or minimum energy performance standards (MEPS) of appliances (GEMS Regulator, 2013). The GEMS Act and the E3 program have had a significant impact on the energy efficiency of air conditioners, in particular window wall units which have increased in size due to the use of larger heat exchangers. As such new for old replacements will not fit into the void left by the old wall or window unit and they are more commonly replaced by split systems
- The *Clean Energy Act 2011* and the *Clean Energy Future Legislation 2011*, which led to the introduction of the carbon pricing mechanism (CPM) – refer to Section 2.8. The high GWP of some refrigerants has increased their value and led to stockpiling and reuse. The Australian Government has tabled Bills to repeal the CPM and it is likely that the passage of these Bills will reduce the value and hence stockpiling of refrigerants.

2.2 State Government and Territories policy framework

The management of waste is primarily the responsibility of state and territory governments who regulate and manage waste in accordance with their respective legislation, policies and programs. Several discrete initiatives were identified to be operating in South Australia, The Australian Capital Territory, and New South Wales that influence the disposal of RAC equipment.

A brief overview of the state government and territory legislation, waste management facilities, information sources and programs that impact the disposal of RAC follows.

Legislation

No legislation specifically mandating the disposal pathway of RAC equipment was identified to be in place at the State Government and Territories level. Landfill fees were found to impact the disposal pathway of RAC equipment and of shredder floc. The presence of programs, pricing, and regulation were common across the state governments and territories. All states and territories were found to be guided by the waste management hierarchy as a framework for managing waste. Broadly, this includes:

- Waste avoidance and reduction programs
- Resource recovery activities
- Reducing the disposal of resources to landfill.

The specific activities that affect the disposal pathway of RAC equipment varied. Western Australia is the only state with a landfill waste diversion target. New South Wales has in place a Fridge Buyback scheme and programs to reduce the transfer of shredder floc to interstate landfill sites. South Australia legislated a landfill ban on Whitegoods in September 2011 (EPA SA, 2012). No other states or territories were identified as having targets or policies addressing the diversion of RAC equipment from landfill.

Information sources

Data provided by State government and Territories is limited in coverage. While several states and territories collect information through annual local government waste surveys, the data does not distinguish RAC equipment from other types of domestic waste. Adding to this is the complexity of the waste classification which is not uniformly applied.

The *National Waste Reporting* online resource draws together a range of information from Australian, state and territory governments, business, industry, and community organisations to provide a national data set about waste management and resource recovery. Most State governments and Territories provide information that feeds into this online resource.

In New South Wales the EPA collects waste data through an annual voluntary survey that is completed by LGAs. Data is categorised as “whitegoods” and is not disaggregated into RAC equipment type. Reporting of whitegoods varies due to the different ways items are classified including as “ferrous”, “bulky goods”, or “whitegoods”. For example, the reported volume of whitegoods declined from over 12,000 tonnes in FY2008 to less than 300 tonnes in FY2013 (a decline of 98% over six years) however industry reports that approximately 10,000 tonnes of whitegoods was received last year.

New South Wales and the Australian Capital Territory are the only states with a program in place to improve the disposal pathway of RAC equipment. The Victorian program no longer operates. New South Wales has an interim program in place to address dumping of shredder floc.

A summary of the state and territory legislation, policies and programs impacting the disposal of RAC equipment is provided in the following table. Various programs are discussed after Table 22.

Table 2: State and territory waste management and resource recovery legislation and strategies, source: based on discussions with industry stakeholders

| State/ Territory | Legislation | Strategy and programs | Impact on RAC disposal |
|---------------------|--|---|---|
| ACT | <ul style="list-style-type: none"> • <i>Environment Protection Act 1997</i> • <i>Clinical Waste Act 1990</i> • <i>Waste Minimisation Act 2001</i> • <i>Litter Act 2004</i> • <i>Dangerous Substances Act 1990</i> | <ul style="list-style-type: none"> • ACT Waste Management Strategy 2011-2025 • Program: Outreach Program (no longer operational) • The ActewAGL Fridge Buyback initiative | <ul style="list-style-type: none"> • Direct impacts are not clear • No kerbside recovery - residents are required to deliver to resource recovery centres • Disincentives to landfill through pricing and regulation • Fridge Buyback scheme commenced early 2014 |
| NSW | <ul style="list-style-type: none"> • <i>Protection of the Environment Operations Act 1997</i> • <i>Waste Avoidance and Resource Recovery Act 2001</i> | <ul style="list-style-type: none"> • Waste Avoidance and Resource Recovery Strategy 2007 • Programs: <ul style="list-style-type: none"> - Fridge Buyback - Structural Adjustment Program to Assist New South Wales Metal Shredders | Direct impact on RAC recovery through: <ul style="list-style-type: none"> • Broad waste objectives: <ul style="list-style-type: none"> - Waste avoidance / reduction programs - Resource recovery activities - Reducing the disposal of resources to landfill • Structural Adjustment Program: <ul style="list-style-type: none"> - Modernise the industry by minimising or diverting shredder floc from landfill - Reduce transfer of shredder floc to interstate landfill • Fridge Buyback Program: <ul style="list-style-type: none"> - Developed multi-fridge degassing unit - Increased the recovery rate of refrigerators and freezers |

| State/ Territory | Legislation | Strategy and programs | Impact on RAC disposal |
|---------------------|--|--|---|
| Qld | <ul style="list-style-type: none"> • <i>Waste Reduction and Recycling Act 2011</i> • <i>Environment Protection Act 1994</i> • <i>Environment Protection Regulation 2008</i> • <i>Environment Protection (Waste Management) Regulation 2000</i> | <ul style="list-style-type: none"> • Queensland's Waste Reduction and Recycling Strategy 2010-2020 | <ul style="list-style-type: none"> • Cost to dispose of waste to landfill is lower when compared to NSW. This has led to cross border movement of shredder floc from NSW to Queensland |
| NT | <ul style="list-style-type: none"> • <i>Waste Management and Pollution Control Act</i> | <ul style="list-style-type: none"> • No relevant strategy or programs | <ul style="list-style-type: none"> • No direct impact |
| SA | <ul style="list-style-type: none"> • <i>Environment Protection Act 1993</i> • <i>Zero Waste SA Act 2004</i> | <ul style="list-style-type: none"> • Environment Protection (Waste to Resources) Policy • South Australia's Strategic Plan • South Australia's Waste Strategy 2011-2015 | <ul style="list-style-type: none"> • Direct impact as refrigerators are banned from landfill and there have been incidents of illegal dumping • Programs in place to improve the quality of material collected from kerbsides for recycling • Broad waste objectives for: <ul style="list-style-type: none"> - Waste avoidance and reduction programs - Resource recovery activities - Reducing the disposal of resources to landfill. |

| State/ Territory | Legislation | Strategy and programs | Impact on RAC disposal |
|--|---|---|--|
| Tas | <ul style="list-style-type: none"> • <i>Environmental Management and Pollution Control Act 1994</i> • <i>Environmental Management and Pollution Control (Waste Management) Regulations 2010</i> • <i>Environmental Management and Pollution Control (Controlled Waste Tracking) Regulations 2010</i> | <ul style="list-style-type: none"> • Tasmanian Waste and Resource Management Strategy | <ul style="list-style-type: none"> • No direct impact • Broad waste objectives for: <ul style="list-style-type: none"> - Waste avoidance and reduction programs - Resource recovery activities - Reducing the disposal of resources to landfill. |
| Vic | <ul style="list-style-type: none"> • <i>Environment Protection Act 1970</i> • <i>Environment Protection (Industrial Waste Resource) Regulations 2009</i> • <i>Sustainability Victoria Act 2005</i> | <ul style="list-style-type: none"> • Getting full value: the Victorian Waste Management and Resource Recovery Policy • Program: Victorian Energy Efficiency Target (RAC equipment no longer eligible) | <ul style="list-style-type: none"> • No direct impact, however some incidents of illegal dumping due to the cost of landfill • Broad waste objectives for: <ul style="list-style-type: none"> • Waste avoidance and reduction programs • Resource recovery activities • Reducing the disposal of resources to landfill • Reducing illegal dumping |
| <ul style="list-style-type: none"> • WA | <ul style="list-style-type: none"> • <i>Waste Avoidance and resource Recovery Act 2007</i> • <i>Waste Avoidance and Resource Recovery Levy Act 2007</i> • <i>Waste Avoidance and Resource Recovery Levy Regulations 2008</i> • <i>Environment Protection Act 1986</i> | <ul style="list-style-type: none"> • Western Australian Waste Strategy: "Creating the Right Environment" | <ul style="list-style-type: none"> • No direct impact, however there are incentives to reduce waste to landfill and landfill diversion targets |

Notable Programs

New South Wales:

Fridge Buyback: The New South Wales Fridge Buyback scheme provides residents with a free refrigerator collection service. Since 2006 over 50,000 refrigerators have been collected. The program was piloted in FY2007 and has progressively expanded to over 45 councils. The scheme only includes working second refrigerators and upright freezers that have been in regular use, are 200 litres (7.06 cubic feet) or more in size, and built before 1996.

Refrigerator collection must be undertaken by accredited removalists and the householder must contact the program administrators. The collected refrigerators are taken to council depots, degassed and put in a recycling skip for collection. The refrigerant is ultimately transported to Melbourne and safely disposed of by ToxFree under the auspices of RRA.

Through the program, a custom-made multi-fridge degassing unit has been developed that can degas several refrigerators at once. NextEnergy, the program administrators, advised that a high percentage of end-of-life refrigerators still contain refrigerants, which suggests that loss of refrigerant is not the major cause of failure of appliances. It is worth noting that the conditions of the program may result in this being an artificially high estimate.

New South Wales also has in place the “Structural Adjustment Program to Assist New South Wales Metal Shredders”. This program, which is in place until 2017-2018, provides a deduction on the applicable waste levy for shredder floc disposed to landfill in New South Wales. The program is designed to assist modernisation of the industry and remove the market distortion whereby shredder floc was being transported to Queensland for lower cost disposal. In addition a grants program has been established to develop new approaches and technologies to reduce the residual waste produced by metal shredding companies (NSW Government, 2013). A contestable grants funding of up to \$5 million over 5 years has been established to fund this initiative (NSW Government, 2013).

Australian Capital Territory (ACT):

Fridge Buyback: ActewAGL operate a scheme similar to the New South Wales Fridge Buyback program. ActewAGL collect and arrange for the degassing and recycling of working refrigerators built before 1996 (ActewAGL, 2014). The scheme started early 2014.

Outreach Program: The ACT Outreach Energy and Water Efficiency Program was designed to promote replacement of old appliances in low-income households. The program ceased operation about three years ago. Over the operational life of the program 1,587 inefficient refrigerators were replaced. No information was available about the end-of-life pathway of the replaced refrigerators.

Victoria:

VEET: The Victorian Energy Efficiency Target (VEET) increased the recovery rate of refrigerant gases in Victoria. The *Victorian Energy Efficiency Target Act 2007* places an obligation on Victorian energy retailers to surrender a certain number of Victorian energy efficiency certificates (VEECs) each year. Initially the retirement of old appliances, such as refrigerators, was included as an eligible activity for generating VEECs.

Companies such as Ecofeet offered free refrigerant recovery services to LGAs and hard rubbish collectors. In return they were able to claim and then sell VEECs. In August 2013, refrigerators were removed as an eligible activity. As a result degassing companies have exited the market. EcoFeet believes that LGAs had improved their degassing practices for refrigerators as a result of the VEET program.

Waste management facilities

A range of waste management facilities, such as WTS, recycling facilities, landfill sites, and shredders are used to dispose of RAC equipment. Based on the National Waste Reporting an idea of the waste management facilities that could be utilised in the disposal of RAC equipment has been developed.

Across Australia these may include:

- 872 Waste Transfer Stations (WTS) that consolidate waste or resources for recycling
- 520 recycling facilities that, dismantle or sort waste (e.g. e-waste) into material type (e.g. plastics, metals, timber, glass and paper/cardboard) for reprocessing
- 1,168 landfill sites that receive around 20 million tonnes of waste annually
- 12 shredders that process primarily waste metal products into various ferrous and non-ferrous products that might otherwise end up in landfill (e.g. cars, RAC equipment and other whitegoods, light construction steels, demolition waste etc.).

2.3 Equipment wholesalers

Equipment wholesales have limited involvement in the RAC disposal chain after the point of sale. They manufacture or import RAC equipment which is distributed through major retail outlets (e.g. Harvey Norman, Good Guys, etc) and buying groups (e.g. NARTA). They also supply the specialist air conditioning market (e.g. Metallflex, Air Conditioning Warehouse, etc).

A high proportion of RAC equipment is imported¹. Some manufacturers import RAC equipment without refrigerant gas and charge the equipment in Australia. Electrolux manufacture refrigerators in New South Wales (this operation will cease in 2016) and Daikin manufacture ducted air conditioners locally.

A handful of companies dominate the wholesale market and have minimal direct involvement with the householder beyond influencing buying decisions via advertising and promotion in the media. In the majority of circumstances, the retail outlets (not the wholesaler) liaise with the householder to coordinate the purchase, delivery and installation of appliances. In a small number of instances (e.g. special contract arrangements or retail stock shortages), the wholesaler will deliver directly to a household.

When an appliance has failed under warranty, it is serviced on site or replaced. This is generally coordinated through the retail outlets. The wholesaler may request to receive the failed appliance for inspection to identify the cause of failure. When this occurs the products are investigated, degassed and sent to the recycler or used as spare parts. For example, Mitsubishi engage with Reverse E-Waste who responsibly degas and dispose of returned appliances.

Evaporative air conditioners are mainly sold through the specialist air conditioning market. The main suppliers are Brivis, Bonair and Braemar. Whilst data was available from industry on the sale of permanently-installed evaporative air conditioners, there was no data on portable units.

The main equipment wholesalers in the domestic refrigeration and air conditioning markets are discussed below.

¹ More than 75% of refrigerators and 90% of stationary air conditioners are imported as pre-charged equipment (Expert Group, 2013).

Refrigerator (and freezer) market share

Through discussion with stakeholders in the retail and equipment sectors, it was noted that the refrigeration market is dominated by Electrolux, Fisher and Paykel, LG and Whirlpool, with a combined market share of approximately 60% to 70%.

Electrolux manufactures and imports refrigerators. It is also the market leader. Electrolux brands include Westinghouse, Kelvinator, Simpson, as well as the Electrolux brand. Other equipment wholesalers and brand owners (e.g. LG) import units and do not manufacture in Australia.

Air conditioner market share

Through discussion with stakeholders it was noted that the air conditioning market is dominated by four major suppliers: Fujitsu, Daikin, Mitsubishi and Panasonic. Together they comprise approximately 60% to 70% of the market. Mid tier brands include LG, Samsung and Kelvinator, followed by a range of third tier entry-level brands.

2.4 Retail outlets

Retailers interface directly with the householder and are the point of sale in the vast majority of cases for refrigerators and freezers. The involvement of the retail sector in the RAC disposal chain varies. In most cases they will arrange delivery of the RAC item to the household, and will arrange for air conditioner installation.

A sizeable proportion of end-of-life refrigerator collection is undertaken by the retailers when a new refrigerator is delivered and the old refrigerator is removed (i.e. “new for old” replacement). Generally these old refrigerators are stored at the retailer’s distribution centres, degassed, cleared on a weekly or fortnightly basis and sent to scrap metal yards or shredders.

Overall, RAC take-back programs did not appear to be a priority issue for retailers, with the exception of Harvey Norman and the Good Guys. The Harvey Norman scheme is actively promoted on their website. The Good Guys has a premium delivery service, however this is not as well known as the Harvey Norman scheme. The “take back” schemes are discussed in more detail below.

Market share

Retail refrigerator sales are dominated by a small number of large retailers.

Top tier retailers comprise a significant proportion of this market. Industry advised that this is in the order of 60% to 80% of the market. Their estimated market share is: Harvey Norman (30% to 40%), Good Guys (20% to 30%) and NARTA buying group (10% to 30% share)

State-based second tier retailers such as Bing Lee (New South Wales), E&S (Victoria) and Betta (Queensland), comprise 10% to 20%, and David Jones and Myer are relatively minor players in RAC retail. Aldi, Bunnings and Masters are starting to offer whitegoods, but their sales are small.

The market share of suppliers to the air conditioning market is difficult to define because most of the sales are via a large number of trade and specialist outlets. Air conditioners can be installed as part of housing construction or renovation. Portable air conditioners will be sold through retail outlets and discount retailers. The market for second hand air conditioners and reconditioned air conditioners is believed to be negligible relative to sales of new items.

Unconventional markets

There is a limited second hand market for refrigerators and freezers. Due to the widespread ownership of refrigerators and freezers and the variety of disposal pathways, this market is highly fragmented and sales are difficult to quantify.

Larger resellers of second hand refrigerators and freezers operate in major metropolitan areas (e.g. Phoenix Fridges, a subsidiary of the Brotherhood of St Lawrence, operating in metropolitan Melbourne). However, a significant number of second hand sales are known to occur through locally-based retail outlets or online channels such as eBay, Gumtree and Trading Post, as well as through newspaper advertisements.

The Brotherhood of St Lawrence (BSL) collected around 5,000 refrigerators and freezers in 2013, of which only 10% were fit for resale. The remainder are degassed and discarded. This indicates that the quantity sold through Phoenix Fridges is 500 per year.

BSL was not aware of the size of the overall second hand market but believed there were only 'a few' other second hand operators in the market. Assuming there to be about twenty other similar businesses nationwide this is only 10,000 re-sells per year which is not significant in the context of total sales of 995,108 for 2013 (see Appendix C, Table 12). Based on this advice from BSL, the overall second hand market is insignificant compared to the total yearly sales and disposals.

Most refrigerators (80%) collected are pre-1996. Air conditioners are not reconditioned.

BSL disposes of whitegoods to scrap either via scrap metal merchants or direct to SIMS. The value of the scrap is \$150-\$170/tonne, and the average cost of collection is \$25 per unit. The average cost of processing varies and is not possible to quantify.

BSL also indicated that there is a small, but not insignificant, grey market in 'hybrid' refrigerators, which have post-1996 bodies but have been retrofitted with pre-1996 equipment. This indicates that there may still be CFC-charged refrigerators and freezers in the market which have been given a second life rather than being processed for disposal.

It is also noted that while units may not be re-sold, a significant proportion are given away as second hand goods to family and friends through informal channels (Infield, 2007).

Take back schemes

Several retailers operate refrigerator "take back" schemes that can be part of the sales service or can involve a small fee charged by the retailer to the householder.

Harvey Norman was identified as having the most mature "take back" scheme, which is championed corporately and implemented via guidelines to franchisees. The Good Guys also has a scheme, but it appears to be not as well known as the Harvey Norman scheme. Masters provide a fee-based scheme where on request they can take back old appliances. Other retailers may have store level initiatives in place. Overall the quantities that are taken back are significant relative to sales. Because this service is a sales differentiator, retail stakeholders were reluctant to provide figures, however the aggregated information provided by stakeholders indicated that "take back" volumes were between 20 to 40% of total refrigerator sales.

No comparable "take back" scheme was identified for the removal of air conditioners. The common practice is for the old unit to be removed and taken away by the service technician.

Retail industry stakeholders advised that the operation of “take back” schemes has a small commercial gain as well as being a market differentiator. The ability to run the scheme is largely dependent upon the retailer’s consolidation capability (i.e. storage), logistical operations, and the ability to generate economies of scale. Where these factors are in place, the operational costs will be lower than the revenue from the service fee and from selling the old RAC equipment to recyclers for scrap value.

Retailers operating take back schemes have a high level of control over ensuring refrigerators are degassed and recovered for scrap metal value. All refrigerators collected by retailers were reported to have been sold to and collected by metal recyclers. The level of degassing was reported to have improved within the last six months.

Disposal pathways

Once the RAC item is recovered from the household by the retailer, it can take several disposal pathways. The factors that influence the pathway are:

- the type of RAC equipment being recovered
- the qualifications and practices of the trade person engaged to collect the equipment.

Where a trade person is an employee of a specialist air conditioning company responsible for the removal of old air conditioners, air conditioning systems would generally be degassed on site before being removed from the household. Air conditioners collected by trade personnel may be consolidated at their premises, subject to some disassembly (e.g. to recover the compressor and copper) and sent to shredders (or possibly landfill in some instances).

Where a contractor or employee is operating on behalf of a retailer with a “take back” scheme, and where that retailer assumes a product stewardship responsibility, refrigerators would be degassed in bulk by a licensed technician and sold to recyclers for scrap value.

Because the “take back” schemes are not universal across the retail sector, it is likely that in many cases refrigerators are not degassed before being sent to shredders or to landfill. The latter scenario is more likely in rural and regional areas where larger retailers are not necessarily as prominent. Retailers in general are not connected to a “take back” pathway and there are limited opportunities for consolidation, collection, and responsible disposal.

It is noted that the practice of online shopping, whilst having a small share of the retail RAC market at present, is growing and creates opportunities for householders to purchase outside of the major retail networks. This has the potential to create disposal pathways outside of responsible “take back” schemes, which are less likely to be offered by online retailers.

2.5 Service technicians

A service technician installs, services, and removes air conditioning systems at the household location. The technician is generally engaged by the retailer or householder; or is connected to the specialist trade supplier. Service technicians tend to be heating, ventilation, and air conditioning (HVAC) technicians who are licensed to capture refrigerants, install and de-commission air conditioners; however they can also be licensed electricians and plumbers.

The stakeholders generally considered there to be a high incidence of compliance amongst service technicians that are involved in removing air conditioning units. This could be due to a combination of compliance standards in place, training, a greater level of awareness of the requirements, or the ability to charge a fee for this service. Their involvement in the RAC disposal supply chain heavily influences the disposal pathway of split system air conditioning systems.

There is limited involvement of service technicians in disposal of refrigerators. Domestic refrigerators are unlikely to be serviced due to cost of servicing versus replacement, and the increased difficulty of servicing new units with integrated construction.

Disposal pathways

The service technician determines the disposal pathway once an air conditioner is removed from the household. Where they are employed by (or contracted to) a wholesaler, retailer, or specialist trade company; the units are taken to that company's distribution centre for disassembly into spare parts or stripped into material components (i.e. metals and plastics) that are either sold to recyclers or sent to landfill.

Smaller, self-employed technicians may consolidate the units at their premises and recover some scrap components, or take them directly to local WTS or landfill sites. From these sites, the units are stockpiled and sold to scrap metal yards. Self-employed contractors may also take the units directly to scrap metal yards for shredding.

The decreasing price of air conditioners, and their increasing availability at retail outlets, creates challenges for their responsible disposal. A householder who buys a split system from a discount (or online) retailer at a reduced price, will have less access to (and less desire to pay for) a licensed technician. This may lead to instances of home handymen carelessly releasing refrigerant gases during installation or decommissioning; and may also lead to uncontrolled disposal. This practice is illegal as regulations prohibit the discharge of refrigerants (refer to section 2.1).

In the evaporative air conditioner market only 15% of sales are replacement. Because of their low scrap value, the installing technician would generally take the old unit directly to landfill.

2.6 Households

The householder influences the end-of-life of the RAC equipment and the disposal pathway. When the householder disposes of RAC equipment, the pathway it takes is primarily influenced by convenience and cost. Air conditioners typically reach end-of-life when they fail. Refrigerators and freezers reach end-of-life based on consumer model preference as well as failure.

Refrigeration

The purchase of new refrigerators is mainly driven by a desire to have the newest model with the latest features (e.g. two doors, chilled water, better aesthetics, etc), and not necessarily due to performance failure.

Over time refrigerator door seals wear, internal shelves break, and the exterior discolours; however they are still functional. Through discussion with stakeholders it was advised that 80% of refrigerators at end-of-life still contain refrigerants. The refrigerator market is largely saturated and hence the majority of sales are replacements (greater than 80%), with sales into new homes and renovations making up the difference.

A study undertaken by Infield in 2007, found that approximately 60% of refrigerators that had been replaced remain in stock as second hand goods. This indicates that a significant proportion of refrigerator sales are upgrades, and not necessarily replacements of faulty items.

The stand alone freezer market is in decline. Freezers that are attached to a refrigerator are more compact and reliable than the older model chest freezers.

Air conditioners

The domestic air conditioning market is not saturated. Unlike the refrigerator market, not all homes have air conditioners. Demand for air conditioned spaces is increasing; hence the market for air conditioners is growing. The drivers in this market are different to the drivers in the refrigeration market.

The increased uptake of air conditioners is driven by:

- A greater householder expectation for thermal comfort
- Increased affordability. Over the last ten years global production efficiencies have kept the manufacturing cost of air conditioners low. The industry expects that this will continue
- Air conditioners are considered a standard feature in new homes
- More than one air conditioner can be installed per household (i.e. a split system in every room) whereas many homes will only have one refrigerator (especially apartments).

Sales have predominantly been into homes that do not currently have air conditioners. Demand for air conditioners has grown threefold since 1998. A large proportion of these units will reach the end of the life within the short term and will increase the number of air conditioners entering the disposal pathways.

Disposal pathways for householders

The disposal pathways include:

- The Local Government Authority's (LGA) hard rubbish collection
- A service technician replacing an air conditioner (i.e. new for old replacement)
- Retailer removing the old RAC (i.e. new for old replacement)
- Householder taking the RAC to the local WTS
- Illegal dumping.

Illegal dumping is known to occur in regional areas (due to higher disposal costs and less disposal infrastructure) and in remote areas such as plantations and state forests, particularly in South Australia due to the banning of refrigerators from landfill and in New South Wales due the cost of landfill disposal. At a national level this is not a significant issue, however illegal dumping can have significant visual impact at a local level, and in some cases may represent a health and safety issue.

2.7 Local Government Authorities

LGAs are a critical stakeholder group in the RAC disposal chain. Many State Governments and Territories have strategies in place to reduce waste sent to landfill (see Section 2.2). LGAs are responsible for the execution and management of these strategies for collection and disposal of household waste by:

- Ensuring that undesirable environmental and social outcomes do not occur
- Ensuring that useful resources do not end up in landfill
- Extending the life of landfill sites.

LGAs are incentivised to divert RAC waste from landfill to reduce the burden on landfill sites.

A significant proportion of the WTS or landfill facilities are owned by LGAs. However, the operational control varies as it can either be controlled directly by the LGA or by a contractor on behalf of the LGA. A high percentage of recovered RAC is recycled by the LGAs.

Most LGAs offer households a kerbside bulky waste collection service (kerbside collection service or “on call” service). This service is not offered in the ACT, where householders have to transport the item to a depot or retailer. Industry stakeholders advised that RAC equipment can be disposed of at waste transfer stations (WTS) or landfill sites. Householders and service technicians tend to utilise this service.

Disposal costs

LGAs charge a gate fee for disposal of the RAC equipment and incur a cost for refrigerant recovery. Diverting RAC from landfill lowers waste management costs as it can extend the operating life of a landfill and generate an income from the sale of RAC items to metal recyclers.

Shredder floc is disposed of to landfill. Each State and Territory in Australia has some form of waste levy to encourage waste avoidance and resource recovery. There is some interstate movement of shredder floc from New South Wales to Queensland due to lower landfill fees that apply in Queensland. There is also evidence of shredder floc contributing to illegal dumping.

Data provided by the Department indicates landfill levies of between \$40 and \$50 per tonne in South Australia and Victoria; and \$100 to \$120 per tonne in New South Wales. The levy of \$12 per cubic metre in Western Australia equates to about \$30 per tonne. In Queensland, the waste levy was repealed on 1 July 2012 through an amendment to the Waste Reduction and Recycling Regulation 2011 to provide for a nil levy rate on all waste. The New South Wales Government has established a structural adjustment program to assist New South Wales metal shredders (NSW EPA, 2013)

Collection

The kerbside collection (also referred to as hard rubbish or verge) practice varies. Generally it involves either a controlled “on call” pick up service or a zoned collection period. The extent to which this is in place across all councils is unclear; however it appears to be common in urban LGAs. Industry participants reported that this pathway accounts for about 30% of refrigerators reaching end-of-life. Where these services do not operate, there is a greater chance the householder will take the RAC equipment to the local WTS, landfill sites, or illegally dump the item.

Split and ducted air conditioners are generally collected by service technicians or builders. Other RAC items (refrigerators, portables and window walls units, and evaporative air conditioners) tend to be disposed of through kerbside collection. Where LGAs perform the kerbside collection, the RAC items will be sent to WTS or landfill sites.

There was a strong theme across the stakeholder group that items left out for kerbside bulky waste collection will be scavenged for metal content prior to LGA pick up. There is no clear idea on the tonnage that this would amount to but it was considered to be significant compared to overall disposal. Industry participants reported that there is no recovery of refrigerant gases in this pathway, and that this pathway may represent 20% to 30% of refrigerators reaching end-of-life (or approximately 50% of the RAC equipment sent for kerbside collection).

Where LGAs have engaged contractors to collect and dispose of kerbside bulky waste it is common practice for the contractors to sell the RAC equipment to scrap metal yards or take the loads directly to shredders and recover the scrap value.

Disposal

Across the metropolitan sector, there was a strong representation of LGAs having contracts in place with scrap metal companies. For example, approximately 60% to 70% of LGAs across New South Wales have contracts with scrap metal companies to collect RAC equipment. At remote unmanned sites there is less control; however there were reports of rudimentary separation zones being provided.

At the WTS or landfill site, the operator separates and consolidates RAC equipment into a stockpile. The consolidated RAC is stripped into parts, stockpiled, or loaded directly into scrap metal bins. Ideally the RAC equipment is degassed before it is separated into parts or sold to the metal recyclers; however the level of degassing appears to be inconsistent across the sector.

Generally there will be a working stock of RAC equipment at different collection points (e.g. WTS) in collection areas or bins. When volumes are large enough to justify transportation of a full load, they are sold to metal recyclers (in some cases they collect their bins). In regional and remote locations, RAC volumes are lower and transportation costs are high. These factors diminish the returns from recovering the metal in RAC equipment.

Where the RAC is stripped into parts at the WTS or landfill site, the carcasses are disposed of into landfill as well as to shredders.

Typical; supply chain costs reported by the industry are:

- \$20 per unit for pickup
- \$10 to \$15 per unit for metropolitan transport
- \$20 to \$30 per unit for regional transport.

Storage costs are not a significant component of total cost in the RAC disposal chain. The scrap value of RAC equipment drives a high velocity in the disposal chain, from household disposal to shredding. Lack of ready access to “take back” schemes would lead to some temporary stockpiling in regional locations.

While a number of stakeholders mentioned that the distance of regional collection facilities from metropolitan recycling facilities, and the costs involved in transportation, would act as disincentives for recycling in regional areas; most of the stock of RAC equipment will be in metropolitan locations.

Refrigerant gas recovery

Stakeholders indicated that a high proportion of RAC equipment reaching LGAs contained refrigerant gas, possibly as much as 80% (based on number of RAC items, not gas volumes). Disposal (including degassing) of air conditioners appeared to be more controlled.

The extent to which degassing occurs at LGA facilities was not able to be precisely determined. Several LGAs reported that they degas refrigerators, but the practice did not seem to be embedded across all LGAs. The industry believes that coverage of degassing is high for the RAC equipment that is removed by service technicians (mainly air conditioners), but is 30% to 40% for other RAC equipment.

In discussions with a major retailer, and with a recycling company that collected refrigerant gases from retailers, it was noted that there was a high rate of recovery of refrigerant gases from retailers operating “take back” schemes. Discussions with LGAs indicated that recovery of refrigerant gases occurred about half the time. Industry organisations such as the Australian Refrigeration Council (ARC) report that there was likely to be a poor rate of recovery by scavengers, contractors, or scrap metal merchants.

Where degassing does occur, it is initiated by the operators of the WTS or landfill sites. Once the stockpile reaches a certain volume, the operators call a technician to carry out bulk degassing at the WTS / landfill site. Several LGAs reported having personnel trained to undertake degassing.

One New South Wales LGA placed the responsibility for degassing on the metal recycler through a provision in the contract to ensure the regulations were being followed.

2.8 Refrigerant gas collectors

A licence is required to remove refrigerant gases. The industry believes that coverage of degassing is reasonable for the RAC equipment that is removed by service technicians (mainly air conditioners), but the recovery rate for other RAC equipment is 30% to 40%. The main reason for this is the lack of coverage by the servicing sector at end-of-life for refrigerators and freezers.

There is less coverage of domestic refrigeration overall because of the lower quantity of refrigerant gas in these appliances (making it less viable to recover) and the lower level of control over disposal.

Recovery

The incentive for refrigerant recovery is limited due to the cost and time pressures involved. There is a greater incentive to recover gases from split system air conditioners due to the greater quantity of refrigerant involved.

A licensed service technician is required to remove gas from split air conditioning systems. They perform the degassing service as an “add on” to the air conditioner install / deinstall service. This is cost effective because (a) the service may be chargeable, and (b) there is a greater quantity of refrigerant to be removed.

For other RAC equipment, recovering the refrigerant gas is an additional cost burden as a service technician needs to be engaged to recover a small quantity of refrigerant. Rates of refrigerant gas recovery were reported to be about 60 to 100 g per refrigerator, up to 1.5 kg for split system air conditioners, and up to 5 kg for large ducted split systems. .

One company involved in recovering RAC equipment reported that charges for degassing can be up to \$40 to \$60 per unit, however this can decrease to \$20 per unit if there are a large number of units to be degassed. For facilities that regularly carry out degassing (e.g. LGAs, retail consolidators) the most effective option would be to put an existing employee through a one-day certification course. This would enable degassing to be carried out without incurring a “call out” and service fee.

RRA and several other stakeholders reported that whilst the recovery rate of refrigerant gases had been maintained, less was being sent to destruction due to stockpiling and reuse since the introduction of the carbon price.

The incentive for refrigerant recovery is limited due to the cost and time pressures involved. There is a greater incentive to recover gases from split system air conditioners due to the greater quantity of refrigerant involved. A refrigerator typically contains about 100g of refrigerant gas. However a split system (non-ducted) air conditioning unit contains about 1.5 kg.

Gas is generally recovered by a licensed service technician during the servicing and removal of split air conditioners. The ARC felt that refrigerant recovery through this process was high.

Where RAC equipment has been stockpiled at WTS, landfill site, or a retailer’s distribution centre; licensed technicians are more likely to be used. However, the extent to which this occurs is unknown. It is believed recovery is greater in New South Wales due to the Fridge Buyback scheme – refer to Section 2.2 for more detail.

Disposal pathways

Contractors (e.g. service technicians) collect the gas and take it back to refrigerant wholesalers (e.g. A-Gas) who decant it into 0.5 to 1 tonne containers. These quantities are further consolidated by refrigerant wholesalers, and destroyed by ToxFree in Victoria, using a plasma arc process. ToxFree operates the only facility approved to carry out this process in Australia.

Stockpiling of refrigerants with high Global Warming Potential (GWP) has occurred following the introduction of the carbon pricing mechanism. This is due to the large multiplication factor applied to the fixed carbon price. In addition, industry advised the recycling of “dirty” refrigerants into appliances during servicing is occurring across the industry.

Recycling has become more commonplace in recent years due to sustained increases in the price of refrigerants and the introduction of the equivalent carbon price. The quantity of refrigerants recycled each year as a result of these factors is unclear but the practice has led to a drop off in collection from about 500 to about 300 tonnes per year (in a total accessible market estimated by RRA to be about 1,200 tonnes). Collection volumes are expected to recover with the removal of the carbon price.

In the cases where refrigerant gases are not recovered, they are invariably released to atmosphere. Kerbside removal of refrigeration coils and compressors can also lead to the release of refrigerant gas.

The metal recycling industry also reports that gas is lost due to damage of RAC equipment:

- (i) In transit between kerbside and WTS
- (ii) Due to handling at WTS
- (iii) In transit to metal recyclers
- (iv) At the metal recyclers.

Figure 4 below shows a representation of the refrigerant gas collection and disposal chain. The red arrows represent the uncontrolled losses of refrigerant gases to the environment.

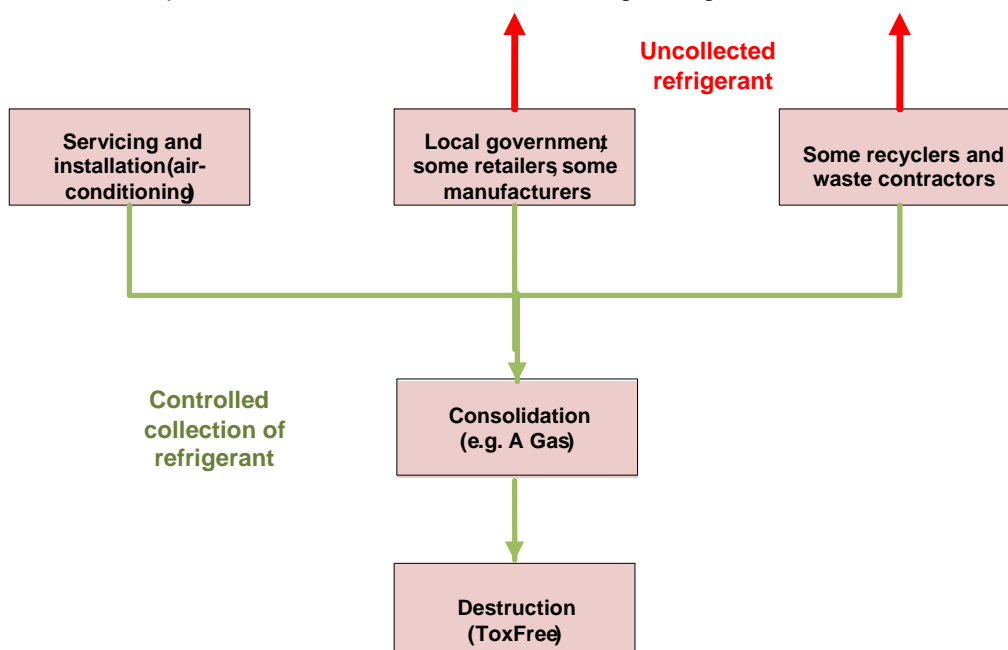


Figure 4: Refrigerant gas collection and disposal chain, source: based on discussions with ARC and industry stakeholders

2.9 Metal recyclers

The final part of the disposal chain is scrap metal merchants and recycling companies. There are approximately 800 – 1,000 scrap metal merchants operating across Australia. These are mainly independent operators that receive scrap metal from kerbside scavengers (also referred to as small door traders), contractors (to LGAs and retailers), and service technicians. These companies mainly sell their scrap metal to the recycling companies after some rudimentary separation to recover items of saleable value, such as compressors and copper.

The main recycling companies are OneSteel, SIMS, Sell & Parker and Norstar. These companies operate 12 shredders in Australia. Most scrap metal is exported to China and South East Asia, but some recycled steel is used in the Victorian and New South Wales steel mills operated by Arrium and Bluescope.

Shredding involves mechanical size reduction, followed by separation into metallic and non-metallic components by magnetic, eddy current, gravimetric, and other processes. At some shredders, the technology enables further separation into ferrous and non-ferrous components. In New South Wales and Victoria most of the ferrous shredder output is sold to steel mills. It is not cost effective to transport the shredded metal interstate, so output from other states is directly exported to China and South East Asia for steelmaking.

There were divergent views on the proportion of shredder feed that was made up of RAC equipment. Estimates ranged from 5% to 10%, but other estimates suggested less than 1%. This range of views could be due to localised factors (e.g. contracts in place for collection of vehicles) as well as inconsistent classification. The higher end of the range might be attributed to the increasing practice of dismantling vehicles before they reach the shredder to recover spare parts for sale to China, which increases the relative proportion of RAC equipment as shredder feedstock.

Whilst the recyclers may collect data on categories that include RAC equipment (e.g. “white goods”, “light steel” or “vehicles”), no data on RAC volumes was specifically collected.

The contribution of RAC equipment to total shredded material has been estimated in this study to be between 1% and 2%. This is based on the total output of metal and floc by the industry, and the metal quantity of disposed RAC equipment (Section 4.5).

No data was available from the recyclers as to the quantity of RAC equipment being received. This may be an area where an audit or survey of shredder feed quantities might be useful.

Scrap metal prices

The recovery of RAC equipment is significantly driven by the market price for scrap metal. Metal recyclers export the majority of scrap metal to China and South East Asia. Some steel is used in Victorian and New South Wales steel mills. Scrap metal is an international commodity and prices for scrap metal are set by the international marketplace.

At present, scrap metal prices are sufficiently high enough to incentivise scrap metal merchants, scavengers, and scrap metal recyclers to recover the metal content of end-of-life RAC equipment. A split system air conditioner has a greater scrap metal value compared to a refrigerator or evaporative air conditioner.

Scrap metal values were reported to be:

- 50 to \$100 for split air conditioning units (due to high copper content)
- \$5 per kg of copper
- \$2 per kg aluminium
- \$180 per tonne of steel
- \$150 per tonne for general white goods scrap.

Collection

RAC equipment finds its way to metal recyclers through the:

- Collection and consolidation by retailers and LGAs
- Opportunistic collection from kerbside items (“scavenger ” pathway)
- Collection and separation by service technicians
- Contractor demolition waste.

Disposal of ducted and split air conditioners is more likely to proceed via collection from service technicians. The industry view is that these stakeholders are likely to separate and sell the metal and some components (e.g. compressors) to scrap metal merchants for a modest fee.

There were only limited examples of refrigerators being disassembled into components for scrap value, and this tended to be for manufacturer product stewardship initiatives.

Builders undertaking home renovations are likely to take their waste directly to scrap metal companies or to shredders. Evaporative air conditioners have little scrap value at end-of-life (due to low metal content and use of non-recyclable plastics) and are typically sent to landfill.

All other RAC items (refrigerators, portables and window wall air conditioners) are likely to be disposed of via collection from LGAs, retailers, and “scavengers”; and then sold for shredding. The industry believes that while LGA pathways dominate, there is a significant contribution from the “scavenger” pathway, which may include some opportunistic removal of copper, aluminium, and compressors; with the “carcass” sent to shredding (or landfill).

Separation

There is limited involvement of scrap metal companies in waste separation. Where this occurs, it is predominately for split or ducted air conditioning units which have appreciable scrap metal value, and hence there is an incentive for separation. Scrap metal merchants are more likely to receive and on-sell separated metals from RAC equipment. It is not cost effective to pay to manually disassemble refrigerators.

When RAC equipment or the separated RAC materials arrive at the scrap metal yard, they are stockpiled into material categories (e.g. appliances, compressors, copper, light steel, etc). However it is more common for RAC to arrive unseparated. It is widely believed that scrap metal merchants in general do not degas the RAC equipment that they receive.

Whilst it was generally not considered by the industry to be cost effective to disassemble refrigerators, the operation carried out by Reverse E-Waste in New South Wales was a notable exception to this. This operation primarily processes electronics waste, but also processes refrigerators for Mitsubishi Electric as part of that company’s commitment to product stewardship on returned refrigerators.

In this operation, the refrigerators are degassed before compressors are removed for sale at scrap value to shredders. Plastics and metals are then separated manually. Metals are further separated into ferrous material and also into aluminium and copper, and sent to shredding. Plastics are separated into grades including acrylonitrile butadiene styrene (ABS) and polystyrene foam, which are compressed and able to be sold for re-use in domestic and export markets.

Additional value-add comes from the higher scrap prices received for the separated materials (as opposed to mixed shredder feed). Complete disassembly takes about one hour per RAC unit, and costs between \$20 and \$30 per unit.

3 Disposal pathways and quantities

This section outlines the significant pathways and estimated quantities of RAC stock and disposal rates at end-of-life. The analysis is separated into two categories: refrigerators (including freezers) and air conditioners as their disposal pathways vary in modes of collection, separation and consolidation.

While it is acknowledged that different states will exhibit different patterns of disposal pathways, purchases and disposal behaviour (particularly due to climatic differences in the Queensland and the Northern Territory compared with the southern states), these trends are not considered to impact on the conclusions that can be drawn at a national level.

The disposal pathways are based on the preceding discussion and on extensive consultation with industry including at a workshop of stakeholders. This process identified three significant disposal pathways for refrigerators, and one significant disposal pathway for air conditioners. Minor pathways exist and are mentioned in some cases, however these are not believed to contribute significantly to the overall material flow, hence only the significant pathways are presented below.

An analysis of sales data for domestic RAC was undertaken to forecast RAC disposal rates and stock levels over the period 2014 – 2024. The analysis is presented at a national level based on a calendar year time scale. This is largely due to the composition of available historical sales data, which is collected on a calendar year basis. The forecast of the estimated RAC disposal rate and stock level is based on historic sales data, forecast sales data, stock in the base year (taken to be 1994), and the estimated life span; as represented in Figure 5.

For more detail regarding the forecasting approach refer to Appendix B.

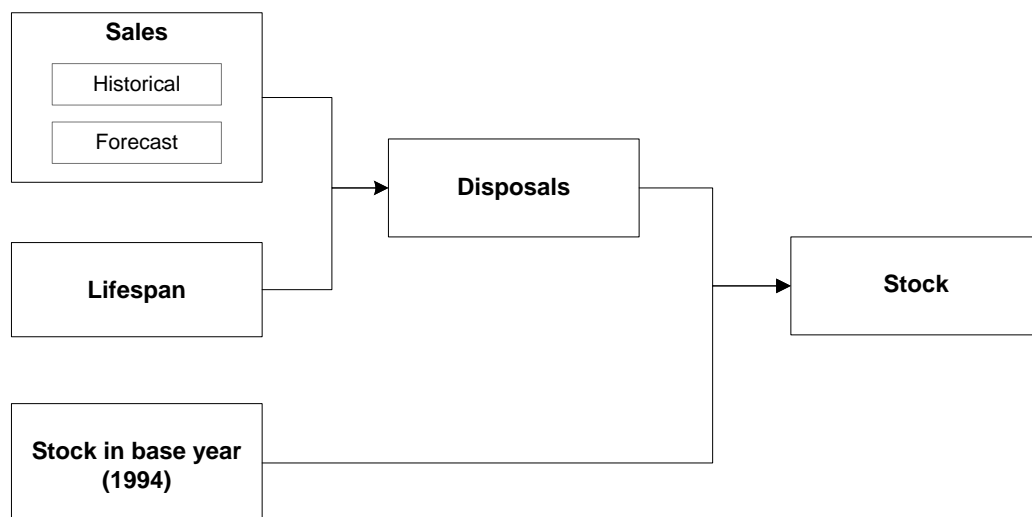


Figure 5: Process used to estimate future stock levels and disposal rates, source: based on discussions with industry stakeholders

3.1 Refrigerators and freezers

The dominant pathway for disposing of refrigerators and freezers is through the LGA or retailers; however there is a high leakage rate across this disposal pathway. The majority of equipment ends up at the metal recyclers.

Pathways

The primary disposal chain for domestic refrigerators involves collection from the household, consolidation and separation into end-of-life waste composition. The stakeholder engagement process indicated that the most significant pathways for the disposal of refrigerators are through:

- (i) Kerbside collection by the LGA; or
- (ii) The retailer, when a refrigerator is replaced. Industry reports collection by the retailers may account for 30% of refrigerators reaching end-of-life.

There is significant leakage in the collection process to scavengers and in some cases via contractors engaged by retailers and LGAs. Scavengers recover RAC equipment from kerbside pickups and sell the items to scrap metal merchants. Contractors can also sell direct to scrap metal recyclers (shredders). The proportion that this uncontrolled disposal pathway accounts for cannot be accurately determined, but industry indicated it may represent 20% to 30% of refrigerators reaching end-of-life (50% of RAC kerbside waste).

Collected refrigerators are consolidated at the following locations:

- WTS or landfill sites by LGA
- Retailer distribution centres (by retailers)
- Scrap metal companies by scavengers or contractors.

There is a high rate of recovery of refrigerant gases by retailers and LGAs, however the rate of recovery by scavengers, contractors, or scrap metal merchants is considered to be poor to non-existent in most cases. As mentioned in Section 2.5, the industry believes that coverage of degassing is good for the sector covered by technicians, but is 30% to 40% for domestic appliances especially at end-of-life.

After degassing, the units are sold to metal recyclers where they are shredded and turned into:

- Shredder floc that is sent to landfill; or
- Shredded metal which is sold.

There are no exports of shredder floc.

The most significant end-of-life disposal pathway for refrigerators is represented in Figure 6 below.

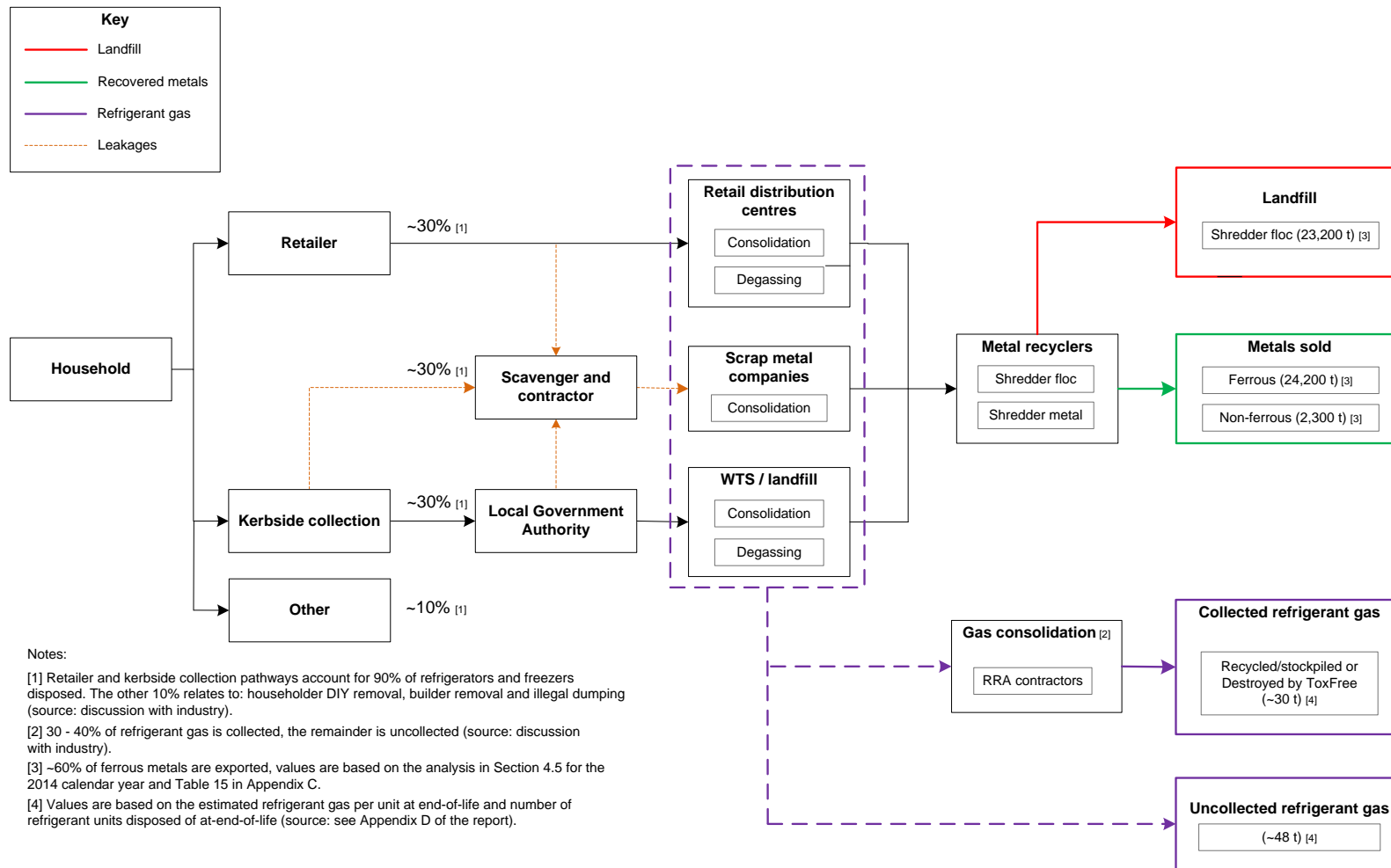


Figure 6: The most significant end-of-life disposal pathway for refrigerators, source: based on discussions with industry stakeholders and Appendix B

Sales

Refrigerator sales remained relatively stagnant until 2002 from when there was an increase in sales lasting until 2006. This can be attributed to the increase in popularity of two door side-by-side refrigerator models (Energy Efficient Strategies, 2010), the aggressive entry of imported brands into the domestic market, and a greater awareness of the higher energy efficiencies of newer appliances. Since then, refrigerator sales have remained at approximately 1 million units per year. Freezer sales were also flat before a brief period of growth in the mid 2000's.

From 2014 onwards, refrigerator sales are expected to continue to grow in line with household growth. This is consistent with the characteristics of a saturated market, in which sales are expected to grow in line with population. Freezer sales are expected to continue to decline as the growth in combined refrigerator/freezer models has decreased the popularity of stand-alone freezers. A contributing factor is the preference for fresh food and frequent shopping, as opposed to storage of frozen food. The assumptions underpinning the refrigerator and freezer sales forecasts are contained in Appendix B.

The analysis shows that combined sales of refrigerators and freezers has averaged 1.1 million units between 2001 and 2010. This is consistent with recent industry estimates of 1.1 to 1.2 million units (Expert Group, 2013). There is a noticeable drop in sales between the final year of historical sales data for refrigerators in 2013 and the beginning of forecast sales in 2014. This suggests that the refrigerator market may not yet be completely saturated, because the forecast sales of refrigerators in 2014 (based on household growth) are less than what is needed to maintain the sales levels seen in 2013. It is possible that the continued popularity of two door frost-free refrigerators will continue to generate additional sales over and above those expected in a saturated market.

Sales of domestic refrigerators and freezers are shown in Figure 7.

Disposals

The rate of disposal of refrigerators and freezers is forecast to increase from around 775,000 units per year in 2014 to 930,000 in 2019 and then grow rapidly to over 1.1 million units per annum in 2024 (Figure 8). This sharp increase is attributable to the onset of retirement of refrigerators and freezers which were purchased in large numbers between 2002 and 2006.

The combined rate of disposal of refrigerators and freezers in 2014 is estimated to be 775,000 units per annum. The analysis of disposals is consistent with the most recently available industry data: in 2012 the analysis estimates 770,000 units per annum compared with Expert Group estimates of 800,000 per annum.

The analysis in the period 2004 to 2010 is likely to underestimate the disposal rate of refrigerators. Stakeholders noted that an increase in disposals was expected around this time as the strong growth in sales of two door refrigerator models led householders to retire their old refrigerators earlier than otherwise expected. This behaviour is not reflected in the analysis, as the life span of each category of RAC is assumed to be constant over time.

However, it is important to recall that disposals in the period 2014 to 2024 are largely a function of sales in the preceding 20-year period, reflecting the estimated life span of the equipment (approximately 17 years). It is noted that the assumed lifespan is consistent with ABS datasets on the average age of refrigerators in households (ABS, 2011). It is also supported by evidence from the Brotherhood of St Lawrence which indicated that the majority of the refrigerators received at end of life are pre-1996 models (i.e. over 18 years old). The estimated disposals of refrigerators in the period 2014 to 2024 is considered to be reliable because they are based upon actual sales data for the period 1994 to 2014.

Forecast disposals in the period 2014 to 2024 should be considered in light of any unexpected spike in sales of refrigerators in the future, as sales over and above the household growth rate – as occurred in 2004 to 2010 – are likely to shift disposals earlier than they would otherwise have occurred.

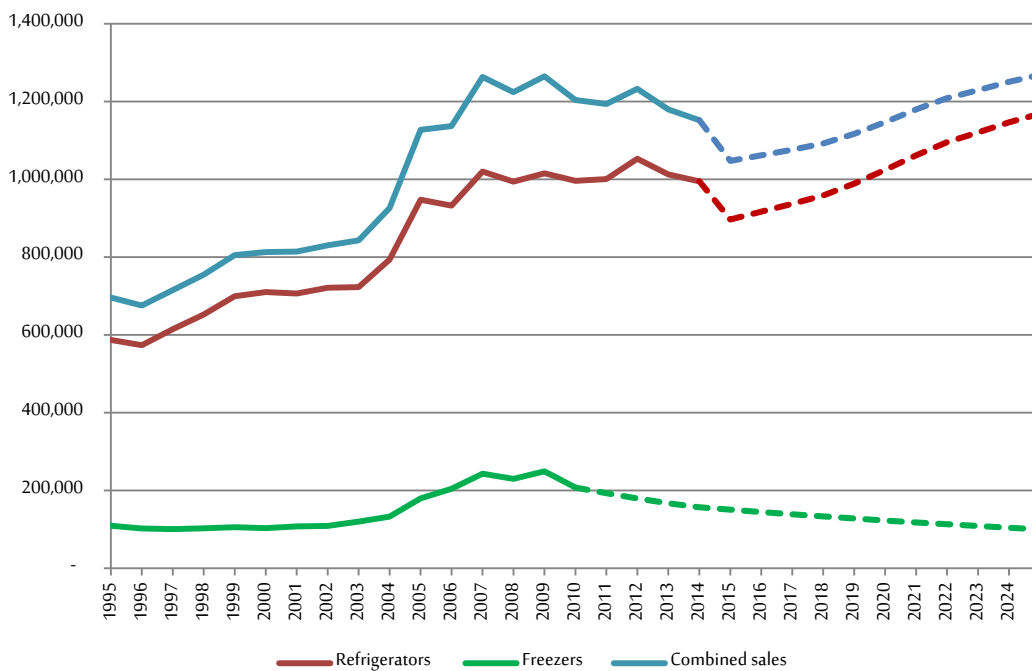


Figure 7: Sales of domestic refrigerators and freezers, source: Energy Efficiency Strategies (2010), personal communication with GfK (2014), additional analysis

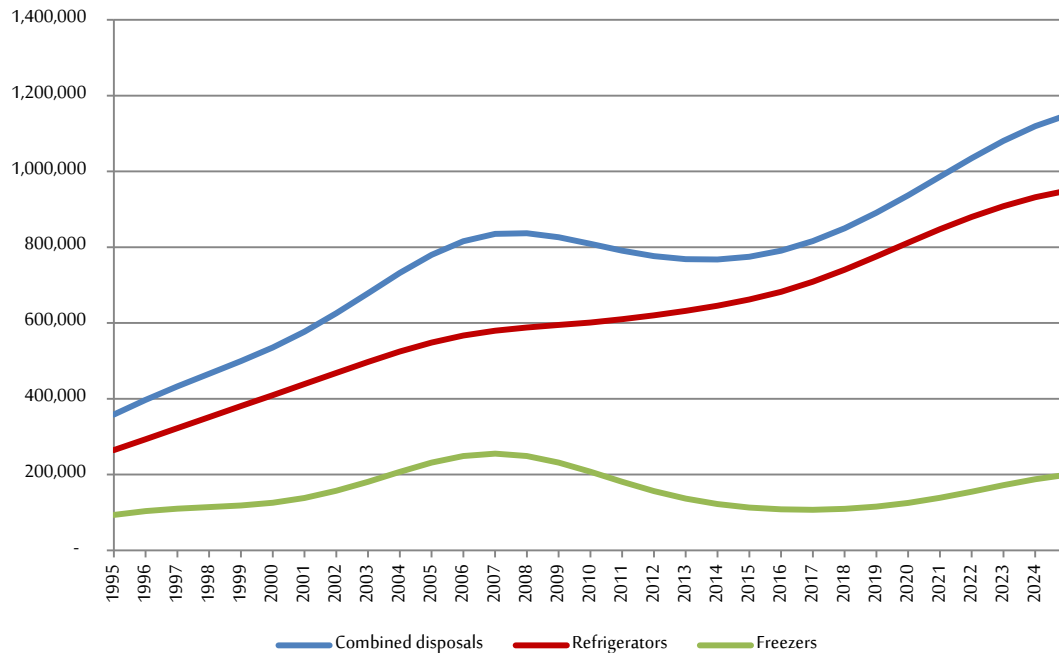


Figure 8: Estimated rate of disposal of domestic refrigerators and freezer, source: additional analysis, see Appendix B and C

Stock

Taking into consideration the trends in sales and disposals of refrigerators and freezers over the 2014 – 2024 period, the stock of refrigerators is expected to increase while the stock of freezers is set to stagnate or decline. This is consistent with stakeholder discussions and publications which describe the refrigerator market as ‘saturated’ and the freezer market as ‘declining’.

The stock of domestic refrigerator and freezers is estimated to be approximately 17.8 million units in 2014, rising to 19.6 million by 2024. The trend in stock is consistent with recent industry estimates (in 2012, the analysis estimates stock of 17.5 million compared to the Expert Group’s estimate of 16.7 million).

Sales and disposals of the combined refrigerator and freezer equipment categories are shown together in Figure 9.

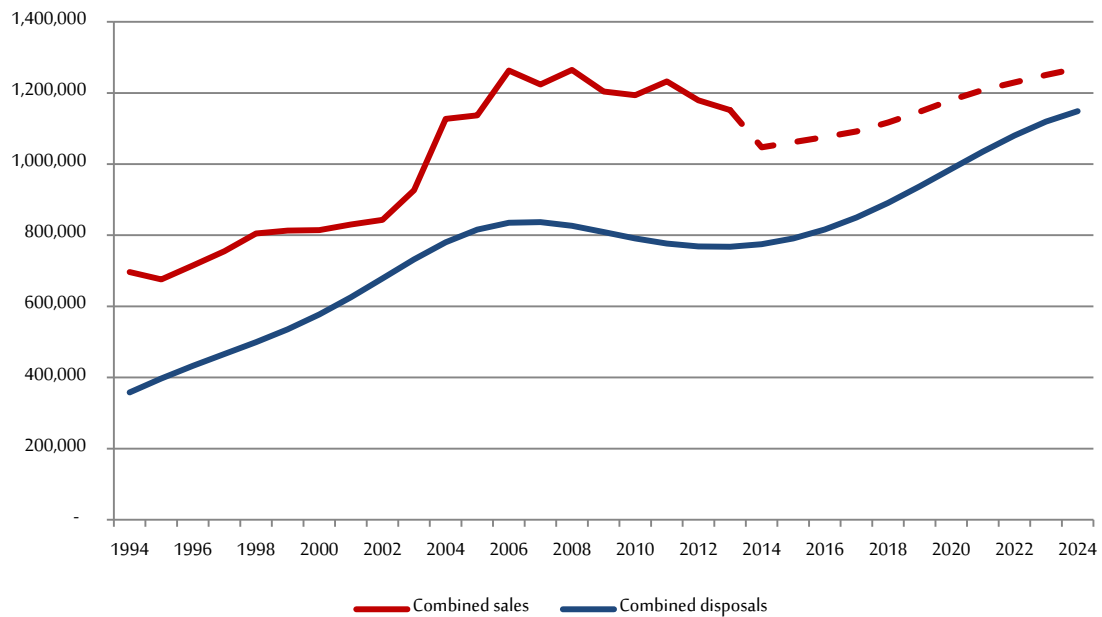


Figure 9: Sales and disposals of domestic refrigerators and freezers, source: additional analysis, see Appendix B and C

3.2 Air conditioners

The dominant pathway for the disposal of air conditioners is via service technicians. In the past 10 years there has been a significant increase in the sales, and hence stocks, of air conditioners; in particular non-ducted split air conditioning units. As a result the volumes of air conditioners that will be disposed of are expected to increase significantly.

Pathways

The stakeholder engagement process indicated that the most significant pathway for the disposal of air conditioners is through the service technician when an air conditioner is serviced or replaced (not including refrigerant replacement). The service technician will degas the air conditioner at the residential location and then remove the unserviceable unit.

Collected refrigerant gas is either:

- Consolidated by RRA refrigerant wholesalers and destroyed by ToxFree; or
- Recycled, or stockpiled for later use.

From collection, the unit takes one of the following pathways:

- The unit is separated into components at the service technician's warehouse. The plastics are sent to landfill and the separated metals are sold to scrap metal merchants or metal recyclers
- The units are sold by the service technician to a scrap metal merchant or to a metal recycler. The scrap metal companies consolidate the units and may do some additional separation (e.g. to recover compressors) and then on sell these to the metal recyclers.

Ultimately the majority of units end up at the metal recyclers where they are shredded and turned into:

- Shredder floc that is sent to landfill; or
- Shredded metal which is sold.

The industry believes that service technicians are involved in removal of split system air conditioners from the home in at least 80% cases of de-installation. For portable (including evaporative) and window wall air conditioners the level is likely to be lower as householders are more likely to dispose of these items through the LGA's kerbside collection service, where one is available. However these are not a significant proportion of total air conditioners reaching end-of-life.

Whilst industry was firm in its view that split systems were disposed of in a controlled manner, increased sales of split systems in general (but especially from discount retail and online outlets), reduced prices, and increased cost-consciousness by householders could lead to unlicensed de-commissioning and uncontrolled disposal pathways, similar to what has been observed with refrigerators. This is despite a higher level of expertise being required in installation (compared with refrigerators). Figure 10 below shows a representation of the most significant end-of-life disposal pathway for air conditioners.

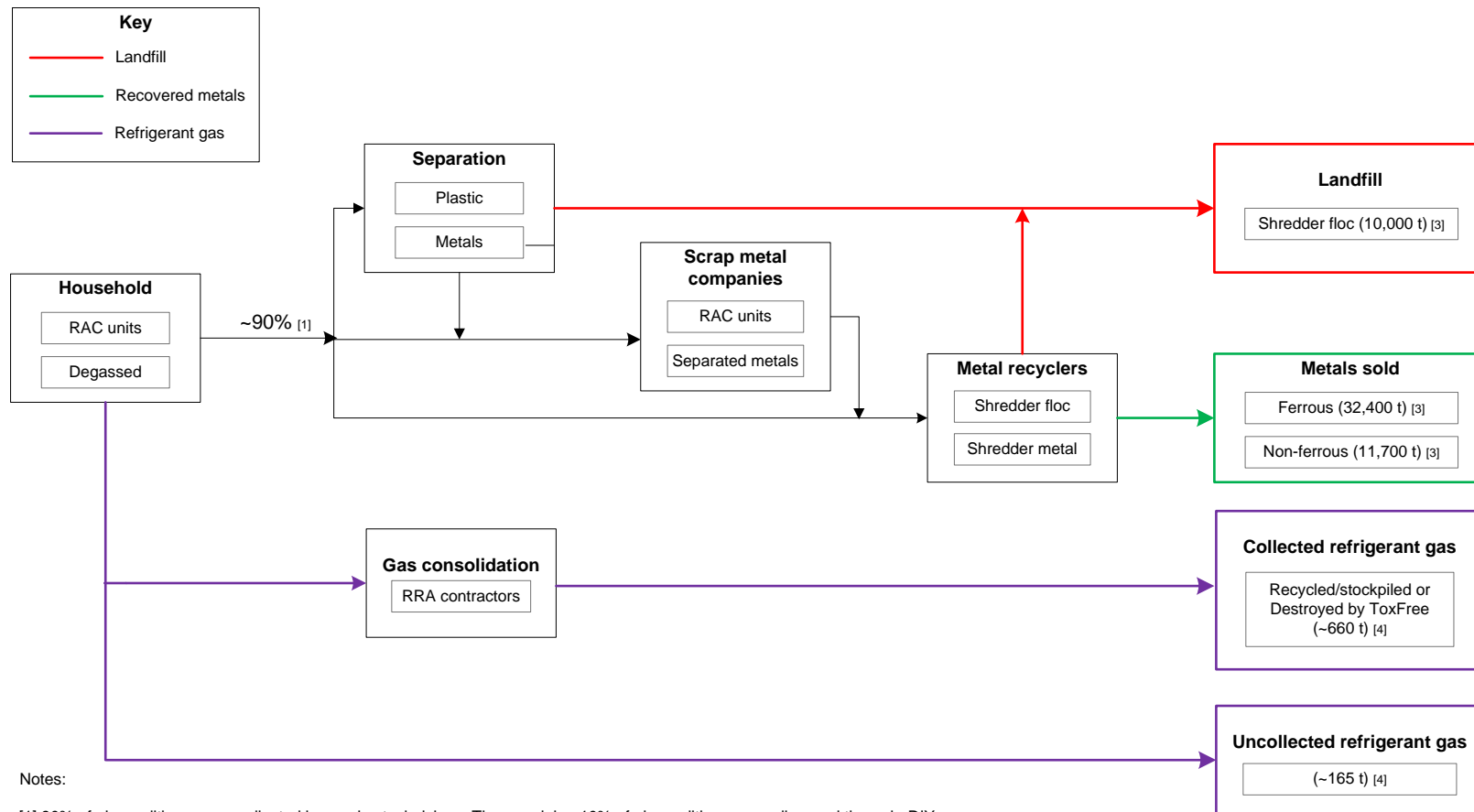


Figure 10: The most significant end-of-life disposal pathway for air conditioners, source: based on discussions with industry stakeholders and Appendix B

Sales

Air conditioners experienced a sharp increase in sales in the period 1999 – 2005 (Figure 11). This increase has been driven by a number of factors including an increase in household purchasing power, a decrease in the cost of air conditioning equipment, and changing consumer attitudes towards thermal comfort. In the period 1999 – 2005, it is estimated that the penetration of air conditioning (i.e. the proportion of households with at least one air conditioner) has increased from around 34% to 60% (Energy Efficient Strategies, 2006).

Sales data shows that the large increase in air conditioner sales has been almost exclusively driven by a leap in sales of non-ducted split system units, which grew from 10% of sales in 1994 to over 60% in 2004 (Energy Efficient Strategies, 2006).

From 2006 – 2013, aside from a brief spike in 2009 (which may have been due to an exceptionally hot summer in parts of South Eastern Australia), sales have decreased to approximately 650,000 units per annum in 2013. Despite this decrease, sales are expected to continue to grow in the period 2014 – 2024, because it is widely accepted that the domestic air conditioner market has not yet reached saturation. This is supported by industry estimates that replacement sales, as a proportion of total sales, are around 10% to 30%, which indicates that most sales of air conditioners are sales to householders who did not previously have an air conditioner.

Sales of domestic air conditioning equipment in 2014 are estimated to be around 850,000 units. The analysis is broadly consistent with other recent estimates of sales (in 2011, this analysis estimates sales of 850,000 units compared to the Expert Group's estimate of 950,000 million units which includes an upwards adjustment for evaporative systems of ~45,000 units).

The rise in sales expected from 2014 onwards is due to the assumption that air conditioner ownership is expected to reach 1.6 air conditioners per household by 2024. This is consistent with the level of ownership of refrigerators, and represents a saturated market. To reach this level requires a significant growth in sales over the next ten years which is reflected in Figure 11. If ownership does not reach this level, the actual sales over the next ten years may differ from the forecast sales below.

As a result of the sharp increase in sales in the early 2000's, disposals are expected to begin to increase significantly from 2015. This is consistent with the sharp rise in sales from 2000 onwards and the expected lifespan of air conditioners of 14 years.

Disposals

The rate of disposal of air conditioners is estimated to be 550,000 in 2014. This is consistent with most recently available industry estimates, which estimate disposals to reach 550,000 one year earlier in 2013² (Expert Group, 2013).

The estimated rate of disposal of air conditioners is shown in Figure 12. This shows that disposals of air conditioners are rising at the fastest rate that has been seen to date, and will continue to rise until a peak of almost 1.2 million units per annum in 2021.

² Expert Group estimate has been adjusted upwards by ~50,000 to include evaporative systems.

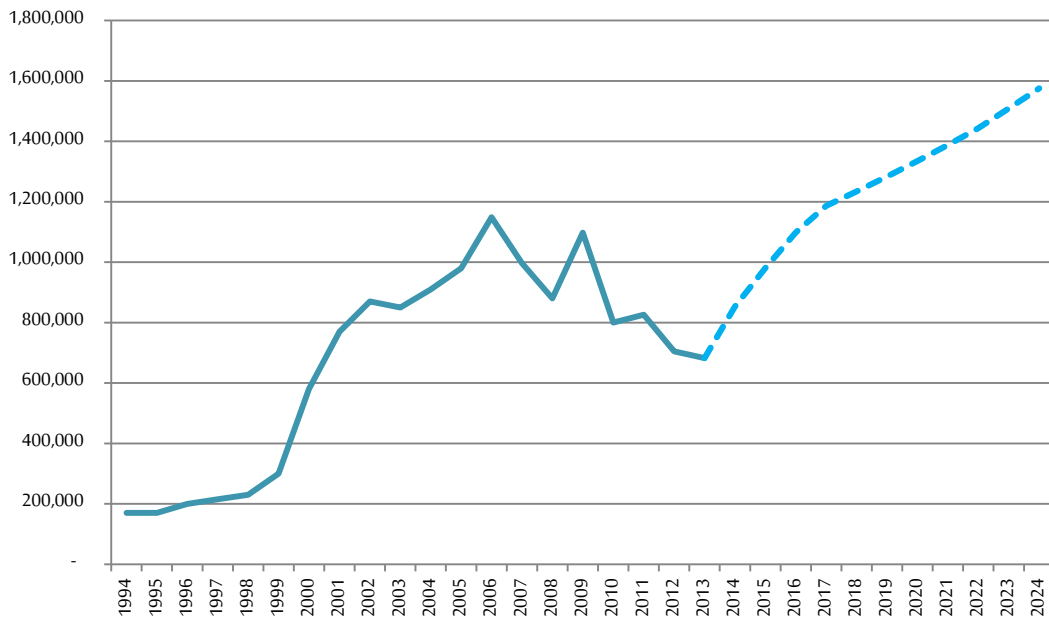


Figure 11: Domestic air conditioner sales, source: Waste White Goods in Australia (2007), ABS 3236.0 (2011), personal communication with GfK Market Research (2014), additional analysis

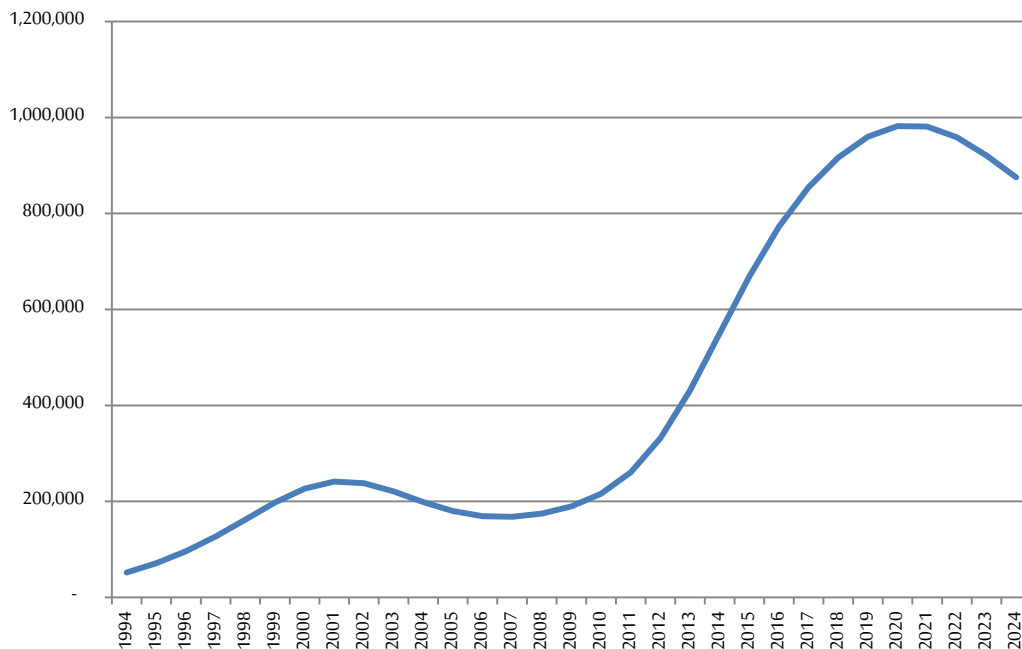


Figure 12: Rate of disposal of air conditioners, source: additional analysis

Although the disposal rate is subsequently expected to fall, this is likely to be a temporary pause since the forecast sales in Figure 11 show that air conditioner sales are expected to increase from 2014 and lead to an increase in disposals beyond 2024.

The sales and disposals of air conditioners are shown together in Figure 13, illustrating the relation between the surge in sales in 2000 and the corresponding increase in disposals that is now occurring. The stock level is expected to reach over 16 million units in 2024.

The changing composition of the domestic air conditioning market has a material effect on the types of air conditioning equipment reaching end-of-life. This affects the composition of disposals in terms of air conditioner type and waste material.

To understand this effect, an assessment has been undertaken of the share of each type of air conditioning equipment at two points in time in the past. This enables the types of air conditioners disposed in the period 2014 – 2024 to be estimated. The information sources used to inform the analysis about the composition of the air conditioning market is outlined in Appendix D.

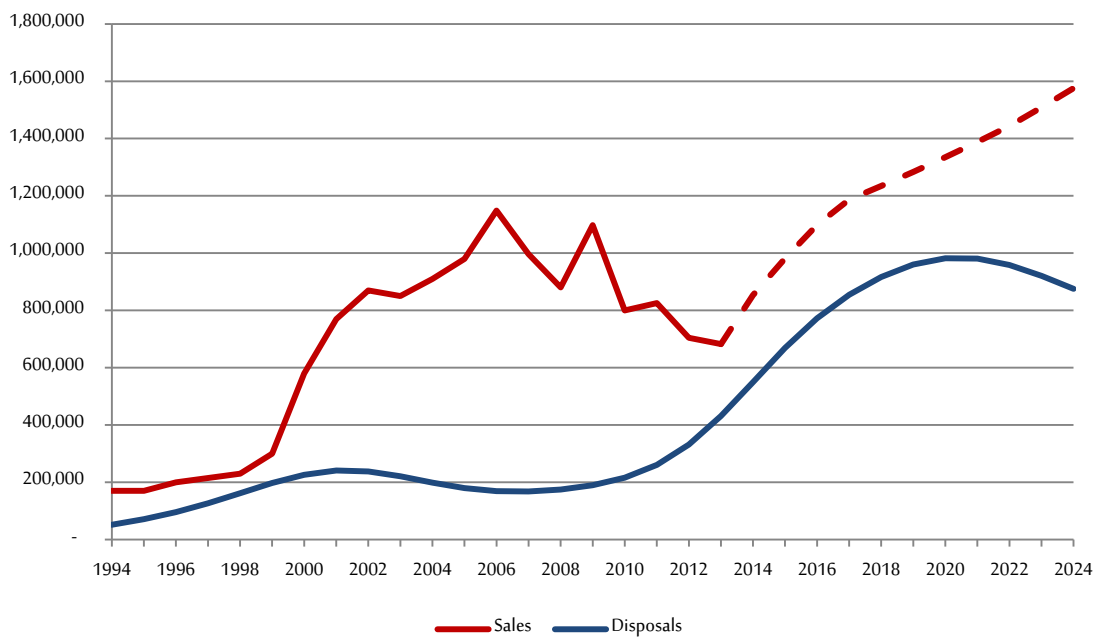


Figure 13: Sales and disposals of air conditioners, source: additional analysis, see Appendix B and C

For the purposes of this assessment domestic air conditioning equipment has been separated into the following categories:

- Portable
- Window/wall
- Non-ducted split
- Ducted split
- Evaporative.

The results of this analysis are presented in Figure 14 below.

The largest change in stock is in the non-ducted split system category, which is estimated to have increased its share of the air conditioner market by 13% since 2000. This has been accompanied by a corresponding decrease in the market share of window/wall and evaporative systems, while portable and ducted split systems have maintained their share of the market.

Due to the changing market coverage of sales data and the exclusion of certain types of air conditioners, particularly evaporative systems, annual sales of air conditioners broken down by type of air conditioner is difficult to ascertain. This makes it challenging to accurately estimate the corresponding amount of disposals by type of air conditioner. However it is estimated that ducted and non-ducted split systems comprise approximately 50% of domestic air conditioners entering disposal pathways in 2014, or 275,000 units, and that this will rise to almost 70% of total disposals, or 620,000 units, by 2024.

This is based on the following assumptions:

- The average lifespan of air conditioners is 14 years (i.e. for a given year, disposals follow sales by 14 years) and so the proportion of sales in 2000 that are split systems is a reasonable predictor of the proportion of disposals that are split systems in 2014.
- In 2000, split systems (both ducted and non-ducted) represented 50% of domestic air conditioner stock (see Figure 14), and it is assumed also represented 50% of sales in 2000 and hence 50% of disposals in 2014 or 275,000 units (50% of 550,000 per Table 13)
- Between 2000 and 2014, split systems have increased their share of the air conditioner market significantly, from 50% to 63% (see Figure 14), which requires sales of split systems as a proportion of all air conditioner sales to be appreciably higher than their share of stock (i.e. higher than 63%);
- On this basis we have assumed that splits represent 70% of sales in 2010 and hence 70% of disposals in 2024 or 620,000 units (70% of 875,000 units per Figure 14). This is broadly consistent with actual sales data from GfK Market Research data which shows that in 2010, split systems represented approximately 70% of total sales excluding evaporative systems, or 64% when sales of evaporative systems are taken into account (~50,000 pa per stakeholder interviews).

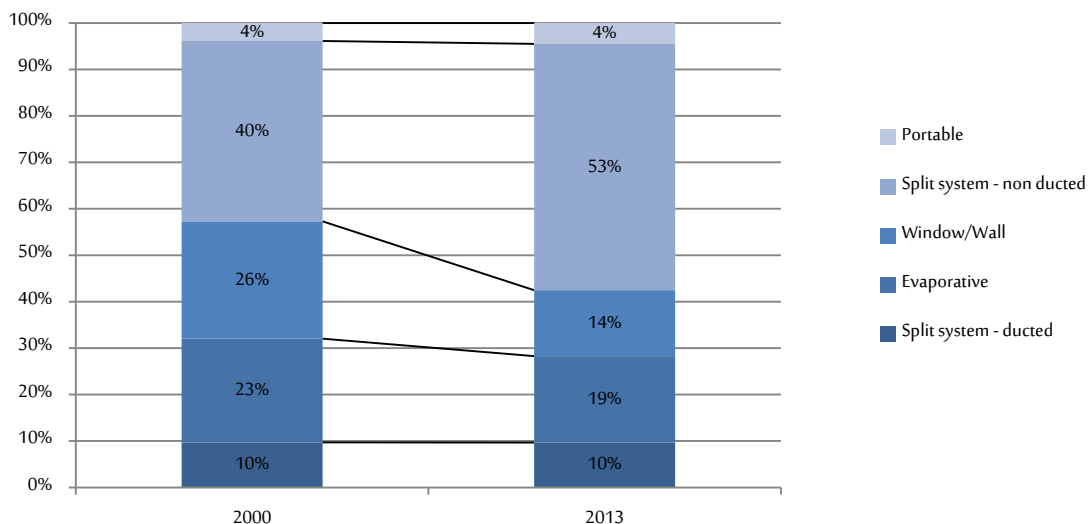


Figure 14: Change in composition of air conditioner stock over time by type, source: DEHWA (2008), Expert Group (2013), ABS cat. no. 4602.0 (2011), additional analysis.

4 Material composition

RAC equipment is manufactured using a variety of materials, both metallic and non-metallic, which are then found in varying quantities in disposal pathways at end-of-life. However, the overwhelming quantity of RAC equipment (complete and fully/partially disassembled) is processed by the metal recycling industry, using mechanical shredding. The by-products from this process are shredded metals and shredder floc.

This section sets out the types of material recovered or disposed of from RAC equipment at end-of-life, based on available literature and stakeholder discussions. Based on the estimated disposal rates in Section 3 and a review of available literature on the standard composition of a RAC unit, the total quantity of each material disposed of annually has been estimated for the period 2014 to 2024, reflecting the potential quantity of each material that could be recovered from domestic RAC equipment in Australia at end-of-life.

4.1 Shredded metal

Shredded metal comprises mainly ferrous metal (iron and steel). Non-ferrous metals, mainly copper and aluminium comprise only 1% to 2%. Ferrous and non-ferrous metals are mainly present in the structure (e.g. cabinet) and machinery (e.g. compressor) of RAC equipment, but are also present in lesser quantities in electronic components including printed circuit boards.

Essentially, all non-ferrous shredder output is exported for recycling through copper and aluminium smelters in China. There has been a limited market in Australia for recycling aluminium, but this will cease with the closure of the Alcoa smelting and processing facilities in Victoria and New South Wales. There has been no market for copper recycling since the closure of the Pasmenco smelter in New South Wales, and all separated copper is exported.

Data provided by the recycling industry indicated that the total output of ferrous scrap is about 3.5 million tonnes per annum. This is for all ferrous scrap, including from RAC equipment but mainly from automotive units. Of this tonnage, about 1.4 million tonnes (40%) is recycled through local steelmaking operations. The balance of ferrous scrap (60%) is exported. On the basis that shredder output is between 1% and 2% non-ferrous material (i.e. relative to ferrous scrap), the non-ferrous component of total shredder output (including from RAC) is between 35,000 tonnes and 70,000 tonnes. All of this is exported.

The contribution of RAC to shredded metal output has been estimated in Sections 4.5 and 4.6. RAC generates about 64,000 tonnes of ferrous scrap and about 15,000 tonnes of non-ferrous scrap. This indicates that whilst the contribution of RAC to ferrous scrap is insignificant, it is a much greater proportion of non-ferrous scrap.

4.2 Refrigerant gas

In order to comply with the regulations, metal recyclers are required to be licensed if they handle refrigerant gases, and to not emit refrigerant gases. It was a widely held view across the stakeholders that degassing does not occur at the shredders, with the main reason for this being that it is not deemed cost effective to separate and check RAC equipment at a shredder for the presence of refrigerant, and to carry out degassing if required. There were only limited examples of degassing occurring at shredders.

It was also noted by metal recyclers that there are numerous opportunities in the disposal chain for RAC equipment to lose its refrigerant charge, including from the activities of scavengers, damage to appliances on pickup, and at LGAs and in delivery to the shredders. Also, it is not easy to ensure if a RAC item is degassed or not. The view in the metal recycling industry is that although the declaration system is not a reliable indicator, the shredders assume that RAC is degassed before it arrives.

4.3 Shredder floc

The non-metallic component of the shredder output is termed “floc” and comprises mixed and low-grade plastics including insulating foam, and is often contaminated with oils and chemicals (e.g. automotive coolant).

There is no economic value in recycling shredder floc (e.g. into plastic types) and it is therefore sent to landfill. It is uneconomic to separate plastic grades from mixed floc. The shredding industry provided information to indicate that shredder output is typically about 16% floc. On this basis, the annual quantity of floc (based on 3.5 million tonnes of shredded metal) is about 700,000 tonnes.

It is difficult to obtain a representative picture of the composition of shredder floc. Overseas studies exist, but they will heavily reflect local materials in their findings. Also, different material categorisations are used across the industry. Given that automobiles represent the major part of shredder input, one reliable data set obtained was on the composition of shredder floc from automotive recycling in Australia (Environment Australia; 2002).

A comparison of the publicly reported data about the material composition in RAC disposal to overall shredder output against the data provided by the recycling industry is provided in Table 3. The recycling industry reports a high waste composition of dirt, rock, concrete, and other small solids.

There has been some interstate movement of shredder floc from New South Wales to Queensland (due to lower landfill fees in Queensland) and some evidence of illegal dumping. The New South Wales Government “Structural Adjustment Program to Assist New South Wales Metal Shredders” is aimed at addressing this market distortion.

Sectors of the industry are also accessing funding from the Structural Adjustment Program, to develop floc re-use and landfill diversion technologies

Whilst there were isolated reports of shredder floc being incinerated or exported, essentially all shredder floc goes to landfill. China no longer accepts shredder floc since the introduction of the Green Fence³ program in 2012. Similarly, there is only limited evidence of RAC equipment at end-of-life being exported to China for reconditioning and reuse.

The Plastics and Chemicals Industry Association (PACIA 2013) reports that the value of mixed plastics has significantly declined since not being accepted into Chinese markets.

³ China implemented the Green Fence program 2 years ago. Prior to this program China was purchasing other countries materials, as they have become more self sufficient they no longer purchase overseas. China no longer accepts the lower grade / cheap mixed plastics.

Table 3: Contribution of RAC disposal to overall shredder output, source: Environment Australia, 2002 and interviews with the Recycling Industry

| Material | Percentage in floc | |
|--|-------------------------------------|---|
| | Source: Environment Australia, 2002 | Anecdotal evidence provided by the Recycling Industry |
| Dirt, rock, concrete and other small solids (1) | - | 37% |
| Plastics (all types) | 38% | 15% |
| Urethane (including foam) | 16% | - |
| Fibre | 13% | - |
| Rubber | 7% | 6% |
| Wood | 3% | 4% |
| Paper | 2% | 1% |
| Ferrous metals | 8% | 10% |
| Glass | 7% | - |
| Wire | 6% | - |
| Non-ferrous metal | 4% | 4% |
| Moisture | - | 10% |
| Glass, ceramics, tiles etc | - | 8% |
| Textiles | - | 3% |
| Fibreglass | - | 2% |
| <i>Note 1: This category includes construction materials that are being recovered for metal content, and also undersized fractions of other materials including plastics</i> | | |

4.4 Other end-of-life materials

Much of the discussion on treatment of RAC equipment at the shredders focuses on the output of ferrous and non-ferrous (copper and aluminium) material, as well as floc and refrigerants. However, from a product stewardship perspective, it is important to consider the fate of other components. These are discussed below.

Insulating foams

Domestic refrigerators contain approximately 5 to 10 kg of insulating polyurethane foam. This foam in turn contains about 5% by weight of blowing agent (KPMG 2012).

Refrigerators manufactured prior to 1995 are likely to contain chlorofluorocarbons (CFCs) as blowing agents. These compounds have since been phased out in all countries as a result of the Montreal Protocol which controls the consumption and production of Ozone Depleting Substances. CFCs were replaced to some extent by hydrochlorofluorocarbons (HCFCs) and later by hydrofluorocarbons (HFCs). However the higher cost of these gases (exacerbated by the phase out of HCFCs) has led to the widespread use of hydrocarbons such as pentane as blowing agents for domestic refrigerators (KPMG, 2012).

Insulating foam will be collected as a part of shredder floc. Whilst there is little quantitative data on the retention of blowing agent, it is likely that much of the blowing agent would be released on shredding due to the increase in surface area, heat of shredding, and the breakdown of the encapsulating metal or plastic structure of the appliance (KPMG 2013).

It is likely that refrigerators still to enter the disposal chain, and manufactured before 1995, will have potential to release CFCs into the environment. In addition, there is still a bank of refrigerators manufactured since 1995 and containing HCFCs and HFCs, that is still to enter the disposal chain.

Plastics

Plastics will comprise the majority of RAC equipment waste in shredder floc. A typical domestic refrigerator will contain about 15 to 20 kg of plastics, mainly ABS, polystyrene, and polyvinyl chloride (PVC) (Environment Australia, 2001).

Some of the plastics may contain flame retardants including brominated compounds which are being phased out under the Stockholm Convention on Persistent Organic Pollutants. There is no reliable data on the level of brominated compounds in RAC equipment. Discussions with the European Electronics Recycling Association (EERA) indicated that the level of brominated compounds in modern white goods was negligible, and had been phased out all together in many products.

As mentioned, there appears to be little scope for further separation and recycling or reuse of the plastic materials in RAC equipment once they have ended up as shredder floc. This is due to cost factors and technology limitations including the difficulty of separation of plastic types.

Printed circuit boards

Printed circuit boards will probably migrate to the floc component of shredding, due to their primarily plastic composition. For this reason, in most studies they will be counted as part of the plastics component of RAC equipment. The United Nations Environment Program (UNEP 2013) has indicated that printed circuit boards could comprise up to 0.3% of the weight of large white goods appliances, but a large variance on this was apparent.

Printed circuit boards will contain minor quantities of other metals such as antimony, beryllium, cadmium, and chlorine in electronic components; as well as small quantities of brominated flame-retardants and lead in solder (IGES 2009; RMIT 2006). Because these metals are a minor portion of RAC equipment relative to their concentrations in other forms of electronics, they are generally not reported in lifecycle studies for white goods.

Shredded circuit boards recovered as non-ferrous scrap may be exported to China for hydrometallurgical treatment to recover non-ferrous and precious metals. This does not generally occur with RAC circuitry because of its lower metal content. Discussion with EERA indicated that a significant proportion of circuit board scrap ends up as undersized material after mechanical breakdown (i.e. it is too small in particle size to be recovered from screens and other processes). The undersized material ends up in the shredder floc.

Mercury

Mercury is contained in the thermostats, sensors, relays, switches, and lighting in RAC equipment. It is difficult to determine whether mercury would be contained in floc or in recovered metal (RMIT 2006). Data from the US EPA (2010) and from the United Nations University (2007) indicate that the quantities of mercury in RAC equipment are approximately 1 gram per appliance according to several industry studies (See Section 4.5). The presence of mercury is explained in more detail later in the report.

Polychlorinated biphenyls (PCBs)

According to the UK HSE (undated), PCBs have been used extensively in electrical equipment such as capacitors and transformers. However, their use in open applications was widely banned in 1972 and they have not been used in the manufacture of new equipment since 1986. Unless an appliance is more than 20 years it is unlikely to contain PCBs. All uses of PCBs were to be phased out by the year 2000.

Data provided by EERA also indicated that the proportion of PCBs in heating and cooling appliances was negligible.

Used oil

Compressors used in RAC equipment contain small quantities of oil for lubrication of the moving compressor parts. The quantities reported range from 200 g (United Nations University, 2007; Nebraska Department of Environmental Quality, undated; US EPA, 2010) for refrigerators; to 1 kg in air conditioning equipment (Environment Australia, 2001).

Where waste oil is being recovered in the disposal chain (e.g. from large air conditioning units) it would be expected that it would be treated as trade waste and processed through existing waste oil recovery programs.

Glass

The glass components of refrigerators (e.g. from lighting) would be recovered in shredder floc. Estimates of the composition of glass in refrigerators varies between 1% (United Nations University, 2007) and 2% (US EPA 2010), but may be higher if glass is used as a decorative feature (e.g. glass door).

4.5 Material weight at end-of-life for refrigerators

The tonnes of materials by type that are contained within the refrigerators and freezers reaching end-of-life have been estimated for the period 2014 to 2024 by applying a typical weight and material composition to the quantity of units reaching end-of-life.

Typical weight

A typical weight and material composition was estimated by reviewing relevant publicly available literature. The sources identified were reviewed and assessed for reliability, comprehensiveness, currency, and consistency with other sources including industry publications and stakeholder knowledge.

Given the variety of makes and models of refrigerators and freezers, and the existence of changing trends in the size of units and the materials used, there is some variability in the composition. This analysis represents the best possible approach on the available data.

The assumed weight has been developed based on the average of multiple sources. For refrigerators the assumed weight was 80 kg, based on:

- Department of Environment & Heritage, 2001; EPA, 2010
- Arcadias Ecolas/RPA, 2008
- Nebraska Department of Environmental Quality, 2014.

For a stand-alone freezer the assumed weight was 52 kg, based on Department of the Environment & Heritage, 2001.

Typical material composition

Refrigerators are predominantly comprised of ferrous metal, non-ferrous metal (brass, copper, aluminium etc), and plastics; which together make up approximately 80% of a typical unit. It is assumed the material composition of refrigerators and freezers will not significantly change over time (Infield, 2007).

A review of the available evidence was undertaken to determine a typical material composition of a refrigerator and freezer. This included the above sources as well as:

- EPA (2010)
- United Nations University (2007)
- UNEP (2013).

These sources were found to be consistent with the Infield report (2007). As such the Infield report (2007) has been taken as the primary reference point with further information drawn from other sources for smaller categories of materials, see Table 4.

The material composition of a typical refrigerator is shown in graphically Figure 15 and for a typical freezer in Figure 16 below:

Table 4: A review of available evidence on the material composition of refrigerators and freezers, source: Infield (2007)

| Material | Refrigerators | Freezers |
|------------------------------|---------------|-------------|
| Steel | 38.1% | 66.0% |
| Non-ferrous metals | 4.0% | 3.8% |
| Plastic | 19.0% | 3.8% |
| Compressor | 13.9% | 1.3% |
| Motor | 3.1% | 0.6% |
| Glass | 1.7% | - |
| Foam | 4.2% | 9.5% |
| Foam blowing agent | 0.2% | 0.9% |
| Oil | 0.3% | - |
| Printed Circuit Board | 0.1% | 0.1% |
| Refrigerant | 0.3% | 0.2% |
| Other materials ⁴ | 15.1% | 13.8% |
| Total | 100% | 100% |

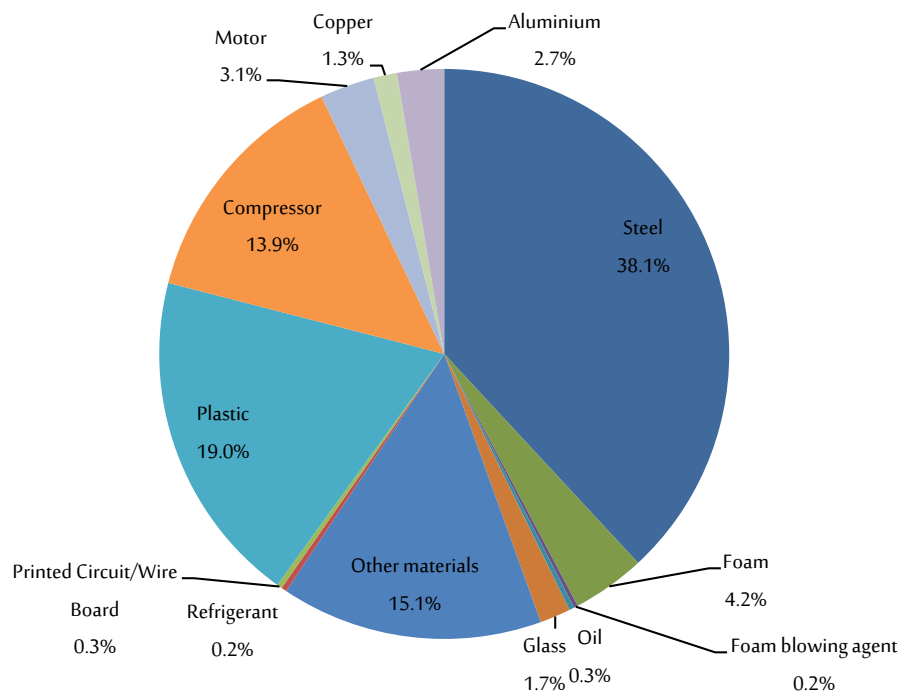


Figure 15: Material composition of a typical refrigerator, source: Table 4

⁴ Includes composite materials and mixed metals.

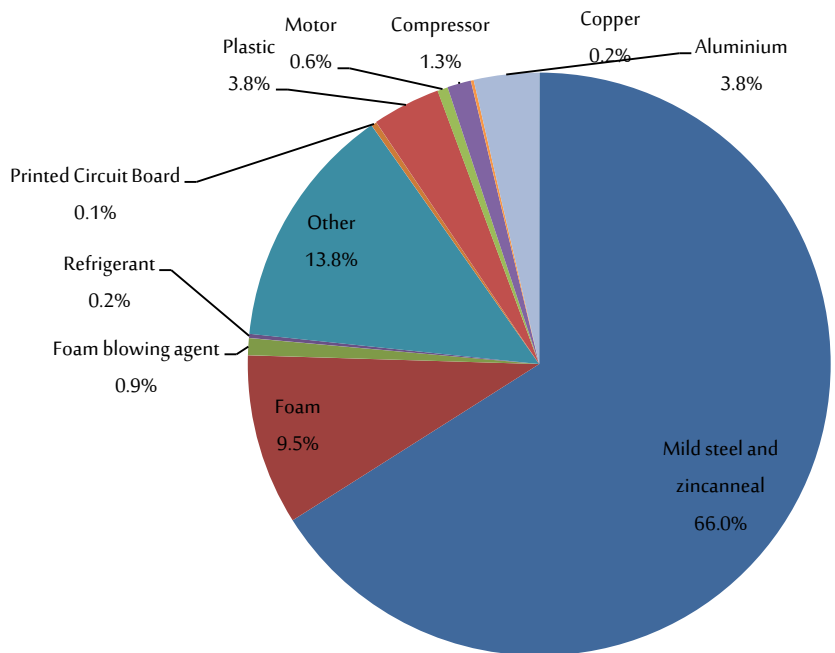


Figure 16: Material composition of a typical freezer, source: Table 4

Material weight at end-of-life for refrigerators

Applying the standard composition of refrigerator and freezer units set out above, enables the quantity of each material disposed in the period 2014 to 2024 to be estimated, as shown in Figure 17 (numerical values can be found in Table 15 in Appendix C – Data tables).

From this it can be seen that ferrous metal accounts for the largest share of refrigerator and freezer waste, and is expected to grow by 33% from 24,200 tonnes in 2014 to almost 36,000 tonnes in 2024.

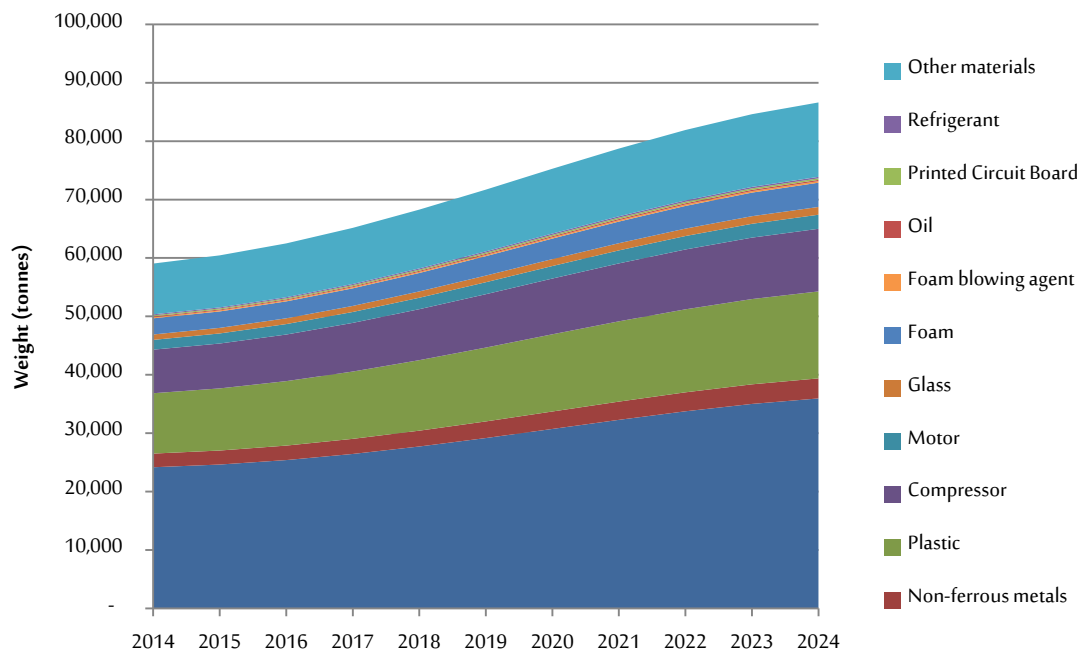


Figure 17: Material composition of refrigerator and freezer waste, source: additional analysis, (note: numerical values can be found in Table 15 in Appendix C – Data tables).

A number of other hazardous materials are contained in refrigerators and freezers including (sources: Arcadis Ecolas/RPA, 2008; EPA, 2010; Nebraska Department of Environmental Quality, 2014):

- Mercury: 1 gram per appliance
- Printed circuit boards components:
 - Lead: 93 g
 - Cadmium: 11 g
 - Hexavalent chromium: nil (Arcadis Ecolas/RPA, 2008, Table 4.36).

Polychlorinated biphenyls have not been used in manufacture since 1986 and so are assumed to be nil. Reliable data was not obtained for brominated flame retardants however these are not expected to be present in significant quantities in modern appliances (EERA).

There was little corroborating data on the quantities of these minor materials, so the levels should be taken as indicative only. Lifecycle data on electronic equipment (e.g. TVs, computers) tends to focus more on these materials because they are present in higher quantities.

The estimated quantities of hazardous materials present in refrigerator and freezer waste are set out in Table 5.

Table 5: Estimated total weight (kg) of selected hazardous materials present in refrigerator and freezer waste, source: Arcadis Ecolas/RPA, 2008

| Hazardous material | 2014 | 2024 |
|---------------------------|-------------|-------------|
| Mercury | 775 | 1,150 |
| Lead | 72,000 | 106,950 |
| Cadmium | 8,525 | 12,650 |

4.6 Material weight at end-of-life for air conditioners

The methodology for estimating the tonnes of materials by type for air conditioners at end-of-life is similar to that applied to refrigerators and freezers. A typical unit, weight, and material composition were determined based on reviewing relevant publicly available literature. These values were then applied to the quantity of units reaching end-of-life (see Section 3.2) to estimate the weight of various materials at end-of-life. Refer to Appendix B for more detail regarding the methodology.

Typical unit

There are several types of domestic air conditioners on the market, each with its own technology. It follows that each type has a characteristic weight and material composition which may be different to other types of air conditioners.

The following analysis has been undertaken for the most common type of air conditioner in the domestic market, namely the reverse cycle split system. None of the sources reviewed for this report included data on the weight or composition of other types of air conditioners such as evaporative, ducted split systems, portables, and window/wall units.

Typical weight

The assumed weight has been developed based on the average of two sources:

- Department of Environment & Heritage (2001)
- Force Technology (2010).

The average weight of a reverse cycle split system unit has been taken to be 101 kg (which is the average between the Department of Environment & Heritage estimate of 83 kg and the Force Technology estimate of 120 kg).

Typical material composition

Estimates of the quantity of waste generated by air conditioner disposals will vary slightly based on the composition of other types in the waste disposal stream. For example, it has been reported that ducted systems consist predominantly of polypropylene (Infield, 2007).

The typical material composition of a non-ducted reverse cycle split system air conditioner is provided in Table 6 and is also represented in Figure 18. This is consistent with Force Technology (2010) and further information drawn from other sources for smaller categories of materials and adjusted accordingly (Department of Environment & Heritage, 2001, Infield, 2007 and Eco 3E, 2014).

Table 6: Material composition of domestic air conditioner, sources: Department of Environment & Heritage, 2001; Force Technology, 2010.

| Material | Composition |
|-----------------------|-------------|
| Steel | 58.2% |
| Plastics | 12.4% |
| Printed Circuit Board | 3.0% |
| Copper | 12.7% |
| Aluminium | 8.3% |
| Refrigerant | 2.4% |
| Other | 3.0% |
| Total | 100% |

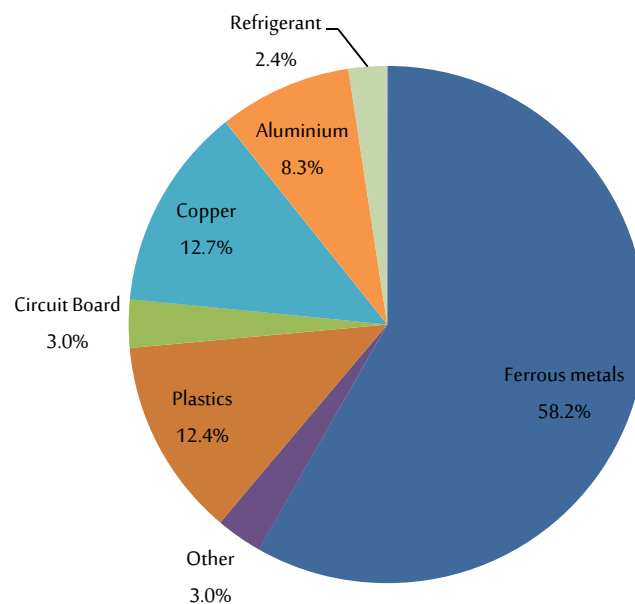


Figure 18: Material composition of domestic air conditioner, source: Table 6

Material weight at end-of-life for air conditioners

Applying the standard composition of air conditioners, as set out above, to the quantity of split air conditioners disposed of, enables the quantity of each material disposed in the period 2014 to 2024 to be estimated, as shown in Figure 19 below (numerical values can be found in Appendix C – Data tables.

From this it can be seen that ferrous metals comprise the largest portion of air conditioner waste by weight, and the quantities are expected to rise by 60% from 32,400 tonnes in 2014 to around 51,700 tonnes in 2024.

None of the data sources reviewed specifically addressed the quantity of hazardous chemicals in air conditioner systems (as distinct from other RAC types). It is known that air conditioners contain appreciable levels of mercury, lead, and cadmium; and that the latter two are predominantly contained in the printed circuit boards of the appliances. On this basis it was initially proposed to estimate the quantity of selected hazardous materials disposed based on the size of an air conditioner circuit board relative to a refrigerator circuit board. This is based on the assumption that larger circuit boards will contain proportionately larger quantities of hazardous materials. However, this assumption could not be substantiated in relation to air conditioners and no corroborating data sources were found. For this reason the quantities of hazardous materials in air conditioners have not been estimated in this report.

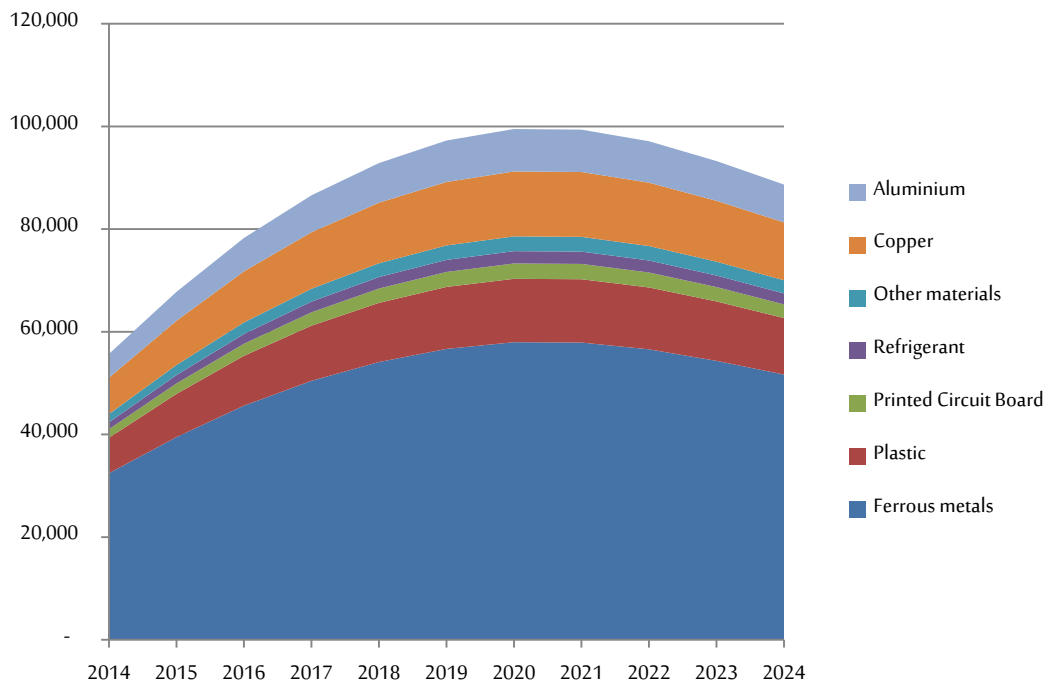


Figure 19: Composition of air conditioner waste, source: additional analysis, note: numerical values can be found in Appendix C – Data tables.

Recoverable metal from RAC

By aggregating the total ferrous metal in tonnes from refrigerator and air conditioner waste, and including refrigerator compressors which are assumed to comprise predominantly of ferrous metal, the amount of recoverable ferrous metal from RAC in 2014 is estimated to be 56,600 tonnes. Similarly, the quantity of non-ferrous metals is estimated to be 14,000 tonnes.

5 Recycling industry dynamics, opportunities and constraints

The ability of RAC equipment to be recycled effectively and with recovery of maximum value (or minimum environmental cost) depends on the overall dynamics of the industry. RAC waste represents a small portion of overall waste including shredder waste and landfill.

5.1 Australian industry

As mentioned above, the annual output of the metal recycling industry is approximately 3.5 million tonnes of shredded metal, predominantly from automobile shredding. Based on the analysis of RAC quantities and material compositions in Section 4, RAC waste contributes about 56,600 tonnes to the total shredded metal output, or only about 1.8%.

There appears to be no capacity limitations in the recycling industry for managing extra RAC equipment. The industry is currently operating at about 50% capacity and running single shifts in some instances. One shredder in Western Australia is due to close in response to low utilisation. There are no indications of additional capacity being planned.

There is a ready export market for ferrous and non-ferrous scrap, and local capability for utilising some ferrous scrap. Whilst the industry as a whole generates a significant quantity (est. 700,000 tonnes) of floc, the overall contribution of RAC to this is small.

Based on a shredded ferrous metal output of 56,600 tonnes (from RAC - see above), and information from the industry that floc is about 20% of the shredded metal output; the quantity of floc derived from RAC would be about 13,000 tonnes. However, the material analysis carried out in Section 4 (based on the typical composition of RAC equipment) supports a higher figure of 34,000 tonnes (i.e. in 2014, non-metal waste from refrigerators is estimated to be 23,000 tonnes per Table 15 and 11,000 tonnes from air conditioners per Table 16).

This is only at most 5% of the total estimated quantity of floc going to landfill, and an even smaller proportion of the 20 million tonnes of waste delivered to landfill each year (Department of the Environment 2013). However, restrictions on the use of landfill for waste disposal would ultimately affect the ability to process RAC waste even though most of the waste is not from RAC equipment.

Barriers to Additional “Value Add” recycling

A high rate of metal recycling is effectively achieved in the RAC disposal supply chain. Ferrous scrap is used in Australia for steelmaking, to the extent that it is available. The remainder is recycled into steelmaking overseas, mainly in China.

Whilst there is no capability in Australia for processing of secondary copper, and limited capability for recycling of aluminium, recycling of these metals is essentially being achieved in offshore markets via the use of Australian non-ferrous shredded metal in Chinese smelters. There is a possible lost opportunity for recovery of precious metals, however discussions with EERA and TES-AMM indicate that there is little precious metal value in RAC waste when compared with electronics waste.

The main loss of value is in the inability to recover plastics from floc, which has no saleable value and which is sent to landfill. From discussions with EERA and the European Union DG Environment (Waste Management & Recycling) Directorate, it is apparent that saleable grades of plastics, predominantly polystyrene and engineering plastics such as ABS, are able to be recovered when RAC equipment (mainly refrigerators) are shredded separately to other types of equipment (such as cars). This enables separation into different plastics types to be carried out based on factors such as density and colour; and prevents contamination from oil, chemicals, and other components.

Recovered plastics can be reprocessed into a range of products including packaging materials (films, bottles), timber substitutes, pallets, outdoor furniture, agricultural and irrigation pipes, insulation, crates, plant pots, carpet underlay, and fence posts (PACIA 2013).

Plastics separated from RAC recycling would have application in a number of existing plastics recycling processes being operated in Australia where plastics are currently being recovered from household waste. PACIA (2013) estimates the size of the plastics recycling industry to be about 300,000 tonnes. In addition, there is a significant export market of about 160,000 tonnes of recycled plastics. Mixed plastics currently have little to no export value, compared with separated grades (DEWHA 2009).

Lower grade plastics such as foam, may be able to be incinerated (e.g. in cement kilns). However, the presence of pollutants in mixed plastic waste would need to be considered.

Controlled recycling of RAC is also carried out in China by TES-AMM and in Australia by Reverse E-Waste. In both cases, shredding (and manual separation) is carried out so as to prevent contamination from lower grades of shredder input materials.

The loss of refrigerant gases in the disposal chain (e.g. due to the degassing not being carried out, or damage to RAC equipment) does not represent a loss of commercial value, because the recovered material is ultimately destroyed (by ToxFree). However, this does represent a significant environmental cost that could be alleviated in several ways:

- Limiting the activities of “scavengers” and unlicensed operators in the RAC disposal chain, by enforcement of regulations and by the use of controlled and designated “pick ups”. An example of this would be the greater use of “on call” collection of end-of-life equipment, as opposed to the equipment being left on the nature strip
- Reinforcing the regulations with LGAs, including requiring them to maintain some basic records of stocks and of degassing
- Encouraging the uptake of “take back” schemes by retailers, by improved visibility and encouragement (and publicity) of partnerships (e.g. with LGAs)
- Where there is an emerging risk of homeowners bypassing licensed installers when they purchase air conditioning equipment (especially split systems) on line or from discount retailers; regulations require retailers make the sale conditional on referral to a licensed installer
- Greater publicity overall of the need to recycle and recover RAC equipment.

The distance of regional waste disposal facilities from metropolitan recycling infrastructure is a disincentive for recycling on these areas. However, the scrap value of RAC items does serve to move them to the metropolitan shredder facilities.

Technology options

During the course of the study, a number of high and low technology options, currently in operation in Europe and China, were identified as delivering improved recycling efficiency, which were as follow:

- The practice of using dedicated RAC recycling facilities prevents contamination of RAC floc by lower grade materials, and enables the implementation of plastics separation. A variation on this approach (and carried out in Europe to a limited extent) is to run RAC equipment through auto shredders in batches or campaigns, so as to separate the RAC waste from other contaminants. However, auto shredders in Australia still do not have the capability for plastics separation based on grade and type (apart from collection as floc).
- If higher grade RAC floc can be obtained by using dedicated shredder lines, then existing technology based on factors such as colour and density would enable separation of plastics into saleable grades (e.g. polystyrene and ABS). This technology is already in operation in a number of waste recycling facilities (DEWHA 2009).
- Controlled atmosphere (or 'integrated') shredding is carried out in Europe to collect refrigerant gases released from the shredding process.
- Increased use of separation of non-ferrous metals into primary grades (copper and aluminium) will enable increased scrap value to be obtained on overseas markets.

A report for Federal Government on Waste Technology (DEWHA 2009) identified a number of emerging technologies for plastics recycling. These included:

- Densification and extrusion (into fuel pellets) to separate plastics from soil material
- Catalytic or thermal breakdown into hydrocarbons (for fuel or chemical use)
- Emerging spectroscopic technologies (e.g. infra red) have the potential to increase the recovery rate and purity of recycled plastics.

5.2 International practices

This section sets out some international approaches to the managed disposal of domestic RAC equipment, with an emphasis on the European experience. A summary of the reviewed international practices and the sources are provided in Table 7, a discussion on each follows.

Table 7: Summary of the international approaches to the managed disposal of domestic RAC equipment, sources: Product Stewardship Institute, 2014; Association of Home Appliance Manufacturers Canada & Retail Council of Canada, 2012; CalRecycle, 2014; Nicol & Thompson, 2007; WEEE Forum, 2012; Institute for Sustainable Futures, 2009; Japan Ministry of Economy, Trade and Industry; discussion with international industry stakeholders.

| Region | Scheme / regulation | Insights |
|--------------------------|--|---|
| United States of America | <ul style="list-style-type: none"> Responsible Appliance Disposal (RAD) Program is a voluntary partnership program | <ul style="list-style-type: none"> Estimated collection rate of RAC disposed annually: 5% Equipment is delivered to appliance recycling facilities Appliance disposal is promoted through: <ul style="list-style-type: none"> – cash incentives – free pick-up – education campaigns |
| Canada, British Columbia | <ul style="list-style-type: none"> Legislated product responsibility scheme for domestic refrigerators and air conditioners | <ul style="list-style-type: none"> No estimated collection rate as currently in the first year of operation Producers of major appliances are responsible for managing products at end-of-life |
| Japan | <ul style="list-style-type: none"> Household Electric Appliances Recycling Law is a legislated product stewardship program | <ul style="list-style-type: none"> Estimated collection rate of Household Electric Appliances disposed annually: 50% Consumers are financially responsible for disposal of goods at end-of-life Manufacturers and importers must take physical responsibility for the goods and recycle them |
| Europe | <ul style="list-style-type: none"> Waste Electrical and Electronic Equipment (WEEE) Directive | <ul style="list-style-type: none"> Estimated collection rate of disposed WEEE: between 30% and 40% Producers are financially responsible for the recovery and treatment of goods at end-of-life The scheme is cost-free to consumers who must be able to return the waste items to collection facilities at no charge |

United States of America (USA)

There is no federal legislation in place governing the recycling of refrigerators and air conditioners in the USA. Twenty three states have product stewardship legislation in place although none extends to domestic refrigerators and air conditioners (the most common products covered include consumer electronics and mercury-containing thermostats).

The largest notable scheme at the federal level, and one which has grown considerably over the past five years, is the Responsible Appliance Disposal (RAD) Program coordinated by the federal Environmental Protection Agency (EPA). RAD is a voluntary partnership program between EPA and state-based utilities and government agencies to recover metals, refrigerant gases, ODS-containing foam, and hazardous chemicals from old refrigerators, freezers, window air conditioners, and dehumidifiers.

The EPA provides program development and implementation services, calculates annual and cumulative program benefits in terms of ODS and greenhouse gas emission savings and potential cost savings, and promotes recognition of the program's partners. To ensure the recovery of foam, appliance recycling facilities cut open the appliance and remove the foam (this can be done manually or with the use of automated equipment), which is then either placed in bags and sent for destruction (incineration) or processed further to recover the ODS or greenhouse gas blowing agent for reclamation or destruction.

Under the Program, which includes manufacturers, utilities, electricity retailers and state affiliates, partners agree to collect old refrigerators, freezers, window air conditioners and dehumidifiers from consumers and deliver them to appliance recycling facilities.

Partners use a variety of tools to encourage proper appliance disposal, including offering cash incentives, providing free pick-up services and running consumer education campaigns to raise awareness about the Program's environmental benefits. The benefits to Program partners include lowering energy demand, improving corporate citizenship performance and meeting legislated or voluntary greenhouse gas emission reduction targets.

In 2011 the program's 42 partners collected and processed almost 900,000 refrigerators, freezers, air conditioners and dehumidifiers, in the process recovering over 347,000 kg of foam blowing agent representing 1.21 million t CO₂-e of avoided emissions. This represents around 5% of the total quantity of RAC disposed in the US annually. Additionally, the cost savings to consumers as a result of the early retirement of inefficient appliances was estimated at \$423,522,700.

Canada

Canada does not have a national scheme in place to manage waste from domestic RAC equipment. However in 2012, the province of British Columbia extended its product responsibility scheme, first introduced in 2007 under the *Environmental Management Act*, to cover large appliances including refrigerators, freezers and portable air conditioners (the program excludes air conditioners which cannot be plugged into a single residential electrical outlets, i.e. ducted systems and non-ducted split systems). British Columbia is the only province to legislate for a product responsibility scheme for domestic refrigerators and air conditioners.

Under the scheme, producers of major appliances (defined to include the product manufacturer, distributor, brand-owner, importer or retailer) are responsible for managing the end-of-life of their products. Producers, either individually or through a representative body, must develop or submit a stewardship program to British Columbian authorities for approval.

In the case of RAC, this is implemented through a processing standard and certification program in which the actors in the end-of-life disposal chain agree to process appliances in accordance with stated requirements. Producers must meet collection targets which are based on reported sales of products. The first full year of the program in operation was 2013 and the first annual report is expected in July 2014.

It is noted that domestic appliances which are used in a commercial or industrial context are considered within the scope of the program.

Japan

Japan has had a legislated product stewardship program for domestic refrigerators and air conditioners in place since 2001, known as the Household Electric Appliances Recycling Law. The program is run under the Basic Law for a Recycling-Based Scheme, which was established in 2000.

Under the program, consumers are financially responsible for disposal of their goods, while manufacturers and importers must take physical responsibility for the goods and recycle them. Collection of RAC occurs through several collection pathways but most commonly retail outlets and post offices. Producers must ensure that the proportion of each category of RAC recycled meets or exceeds a recycling rate. In FY12 the program collected 2.9 million refrigerators and freezers and 2.3 million air conditioners from consumers, which accounts for around half of the total quantity of RAC discarded.

Europe

Europe has had an EU-wide product responsibility scheme in place for domestic refrigeration and air conditioning since 2006 under the Waste Electrical and Electronic Equipment (WEEE) Directive. Prior to the WEEE Directive, Norway and Switzerland and several member states within the EU (notably Belgium, the Netherlands, Sweden), had adopted national regulations and management schemes for refrigerators and air conditioners.

The Directive requires producers to take financial responsibility for the recovery and treatment of RAC at end-of-life. Producers are defined to include importers, re-branders and manufacturers of RAC equipment. The scheme is cost-free to consumers who must be able to return the waste items to collection facilities at no charge. Member States are required to meet a collection target of 4 kg of WEEE per household per annum. In terms of the quantity of WEEE disposed, collection rates currently average between 30 and 40% depending on the jurisdiction.

The method of collection is not prescribed by the Directive. The manner and form (i.e. "how" the Directive operates in practice) is left to Member States to transpose into national law, depending on their national experience. For example, in some jurisdictions, municipalities play a vital role in collection, whereas in others they do not and retailers and recyclers play a bigger role. It is noted that the second hand market for RAC equipment is considered to operate within the objectives of the WEEE II Directive as most goods which are collected illegally eventually end up at an authorised collection point.

The following observations on the EU experience relate to the specific categories of RAC equipment under consideration in this report.

In relation to refrigerators and freezers, that treatment of ODS-containing foam varies from state to state, with some states reporting very high rates of treatment through integrated refrigerator treatment facilities while others rely on manual separation and shredding and subsequent incineration which is considered to be less effective. A significant quantity of foam is shredded without gas collection.

The collection of refrigerant gas has also seen mixed success. A study in 2010 found that up to 50% of refrigerant was lost by the time the equipment reached the point of treatment due to damage to the refrigerant circuit occurring during transport and also as a result of “cannibalising” (i.e. uncontrolled scavenging for scrap metal).

The EU has had a similar experience to Australia in relation to split system air conditioners. These have a primary disposal pathway through certified personnel such as service technicians due to statutory requirements on technicians to be appropriately certified to handle such equipment. There are no specific provisions governing disposal through this pathway as the obligation is on the producer to provide for and finance collection services, even for equipment which requires a person other than the householder for installation and removal at end-of-life.

Retailers who sell split system and other air conditioners are required to direct the buyer to use licensed technicians for installation and to keep a record of installation contracts.

In 2012, following a review of the WEEE Directive, the European Parliament passed an updated WEEE Directive (“WEEE II”). Significant changes to the WEEE framework include higher collection targets for producers (65% of EEE sold or 85% of WEEE generated by 2019) and a broadening of the coverage of the Directive to include all electrical and electronic equipment, subject to certain exclusions.

Illegal dumping and exports of WEEE outside Europe are known to occur. The most effective way of addressing such challenges is considered to be improving the robustness, coverage and rate of collection of WEEE through approved channels. In WEEE II this is expected to be achieved through improved reporting by stakeholders of the quantity of WEEE collected and treated.

Additional control is exerted by regulation of the quantities of refrigerant gases that are available to the market.

Online sales pose a challenge to the WEEE framework as producers outside of the EU may not be familiar with national registration and reporting requirements. To address this issue WEEE II introduces an “authorised representative” role. Non-EU producers can delegate their responsibilities under WEEE II, such as financing, contracting with collection services, registration, and reporting to an authorised representative within the EU.

Producers face a variety of formats for reporting in different Member States, as each jurisdiction has its own registry which can use different forms, reporting and payment processes and frequency of reporting. The European Commission is in the process of harmonising the registration and reporting processes across Member States to facilitate producers’ participation in WEEE II.

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Appendix A – Stakeholder Engagement

Workshops

Stakeholders consulted

Stakeholders were engaged via face-to-face meetings, telephone interviews, participation in a workshop and email correspondence.

Workshop attendees

Objective: To discuss RAC end-of-life disposal practices

Held: 3 March 2014 at Sydney, 10:00 am – 3:00 pm

| Company | Stakeholder group |
|---|---------------------------------------|
| TES-AMM | Waste disposal |
| Ozone Protection and Synthetic Greenhouse Gas Policy Section, Department of Environment | Government |
| Regulatory Affairs, Samsung | Manufacturer |
| Representative | Retailer |
| Refrigerant Reclaim Australia | Waste disposal |
| Mitsubishi / AREEMA | Manufacturer |
| Fujitsu/ Refrigerant Reclaim Australia | Manufacturer |
| Next Energy / Chairman, Tenic | Waste disposal / Refrigerant recovery |
| Daikin | Importer/manufacturer |
| Reverse E-Waste | Waste disposal |
| MRI (Aust) | Waste disposal |
| Department of the Environment | Government |

A full list of the stakeholders engaged over the course of the program is shown below.

Record of stakeholders engaged:

| Organisation | Industry role |
|---|---|
| Australian Council of Recyclers (ACOR) | Recycling industry association |
| Actrol | Seller of air conditioners |
| Air Conditioning and Refrigeration Wholesalers Association (ARWA) | RAC industry association |
| A-Gas | Bulk gas importers Operate a gas reclamation facility |
| Australian Industry Group (AiG) | Industry association |
| Air conditioning and Mechanical Contractors Association (AMCA) | RAC industry association |
| Appliance Industry Association (AIA) | RAC industry association |
| Australian Refrigeration Association (ARA) | RAC industry association |
| Air conditioning and Refrigeration Equipment Manufacturers (AREMA) | RAC industry association |
| Australian Institute of Refrigeration, Air Conditioning & Heating (AIRAH) | RAC industry association |
| Australian National Retailers Association (ANRA) | Retailers association |
| Australian Refrigeration Council (ARC) | Refrigerant handling licences and trading |
| Brivis | Manufacturer of evaporative air conditioning |
| Brotherhood of St. Lawrence | Whitegoods reseller |
| Consumer Electronics Suppliers' Association (CESA) | Manufacturers and importers |
| Coffey Metal Recyclers | Metal recyclers |
| CR Consulting (consultant representing Harvey Norman) | Consultant for Harvey Norman |
| Daikin | Manufacturer / wholesaler of air conditioners and refrigeration |
| Department of the Environment | Federal government policy |
| Department of Industry | E3 program |
| Development Directorate (ACT) | ACT government policy |
| Ecofeet | Degases refrigerators and freezers |
| Electrolux | Manufacturer / wholesaler of refrigeration |
| Environment Protection Authority (EPA) Victoria | Environmental regulator |

| Organisation | Industry role |
|---|---|
| European Commission (Directorate General for the Environment) | European environmental regulator |
| European Electronics Recyclers Associations (EERA) | European recycling association |
| Flouroclaim | Degas refrigerators and freezers |
| GfK | Retail market research |
| Global Product Stewardship Council | Product stewardship |
| Greg Groppenbacher | Consultant on ducted systems |
| Hunter & Central Coast Regional Environmental Management Strategy | Waste management LGA |
| InfoActiv | Product stewardship/ E-Waste management |
| Kiama Municipal Council | Waste management LGA |
| LG | Manufacturer / wholesaler of air conditioners and refrigeration |
| Mindarie Regional Council | Waste management LGA |
| Mitsubishi | Manufacturer / wholesaler of air conditioners and refrigeration |
| Next Energy | State government program Degases refrigerators and freezers |
| New South Wales EPA | State government policy |
| OneSteel | Major metal recycler |
| Plastics and Chemicals Industries Association (PACIA) | Industry association |
| Queensland Dept Environment | State government policy |
| Riverina and Murray Organisation of Councils (AMROC Murray) | Waste management LGA |
| Refrigerant Reclaim Australia | Refrigerant product stewardship |
| Reverse e Waste | Recycling company |
| South Australian Local Government Association | Waste management LGA |
| South East Regional Organisation of Councils | Waste management LGA |
| Southern Cross Metal Recyclers | Metal recycler |
| Sustainability Victoria | State government programs |
| TES-AMM | Global electronic waste recycler |
| Toxfree | Gas collection and disposal |

| Organisation | Industry role |
|--|------------------------------|
| Western Australia Department of Environment and Conservation | State government policy |
| Western Australia Local Government Association | Waste management LGA |
| Waste Management Association of Australia | Waste management association |

Appendix B – Methodology for quantitative analysis

Overview

An analysis of sales data for domestic RAC has been undertaken to forecast RAC disposal rates and stock levels over the period 2014 – 2024.

The analysis draws on historic sales data, forecast sales data, the estimated life span of each category of RAC equipment and the stock in a nominated base year (1994) to forecast the RAC disposal rate and stock level on a yearly basis.

The analysis has been undertaken for two distinct categories: refrigerators (including freezers) and air conditioners. Because of the diversity of air conditioners types in the domestic market, additional analysis on the composition of the air conditioner stock and its effect on disposal rates has been undertaken and is found in Section 3.2.

Although the period under investigation is 2014 - 2024, historical sales data has been obtained back to 1994 to enable a comparison of the outputs of the analysis and actual data, where available, to refine and validate the approach that has been taken.

The analysis is presented at a national level. While it is acknowledged that different states will exhibit different patterns of purchase and disposal behaviour (particularly in Queensland and the Northern Territory compared with the southern states) these trends are not considered to impact on the conclusions that can be drawn at a national level.

Stock and disposals are calculated on a calendar year time scale. This is largely due to the composition of available historical sales data, which is collected on a calendar year basis.

Key inputs

The analysis is based upon two key inputs:

1. Sales data for each product category
2. The expected lifespan of each product.

The key inputs into the analysis are described below.

The other inputs into the analysis are the stock of RAC in a nominated base year, which is 1994, and the forecast sales data in the period 2014 – 2024.

Historical sales data

Actual sales data has been obtained for each category of RAC equipment for the period 1994 to present.⁵ The sources of sales data for this analysis are set out in Table 8 and have been selected based on their coverage of the retail sector, the types of RAC equipment recorded and the length of time for which data is available.

It is noted that depending on the way the sales data is collected, it is unlikely to capture all sales of domestic goods to householders because of sales that occur through non-retail channels such as direct imports or trade sales. Estimates of the market coverage of each source of data have been obtained and each set of data adjusted accordingly to reflect total sales of domestic goods.

⁵ Data on freezer sales was not available for the period 2010 to 2013. Instead, for those four years, sales data has been estimated based on forecasts of freezer ownership during the same period.

Table 8: Sources of historical sales data

| | Refrigerators | Freezers | Air conditioners |
|------------------------|---|---|---|
| Source(s) | Energy Efficiency Strategies, <i>Greening Whitegoods</i> , 2010 (data source GfK Market Research). Personal communication, GfK Market Research, 2014 | Energy Efficiency Strategies, <i>Greening Whitegoods</i> , 2010 (data source GfK Market Research) | Infield, <i>Waste White Goods In Australia</i> , 2007, prepared for AEEMA (data source GfK Market Research). Personal communication, GfK Market Research, 2014 |
| Period | 1994 – 2013 | 1994 – 2009 | 1994 – 2013 |
| Market coverage | 66% – 83% from 1994 – 2005 95% from 2005 – present | 73% – 78% from 1994 – 2005 95% from 2005 – present | 55% – 60% from 1994 – present Adjusted upwards by ~50,000 per annum (Stakeholder interviews, 2014) to include evaporative systems. |

Product life span

Future RAC equipment disposal rates and stock levels depend on the expected life span of the equipment. There are several known influences on the life span of RAC equipment, which can be grouped into physical and behavioural categories as follows:

- Physical influences:
 - Quality of design and assembly
 - Mechanical or physical characteristics
 - Operating environment
 - Patterns of use
 - Potential for re-use or refurbishment
- Behavioural influences:
 - Desire to upgrade to newer goods prior to the existing unit failing (e.g. due to introduction of new technology)
 - Existence of a market for second hand goods
 - Regulatory incentives to encourage uptake of more energy efficient RAC
 - Length of time in storage before RAC is disposed.

Because of these influences, the life span of RAC equipment is inherently variable and difficult to predict and quantify. Further, it is difficult to identify reliable historical data to support quantitative analysis of the factors described above, as well as to predict how such factors may develop over time.

To take this variability into consideration, the life span of each category of RAC has been estimated based on the probability of a unit exiting the stock in a given year.

It is assumed that the life span function of each category of RAC equipment remains constant over time (e.g. a refrigerator bought in 2014 will remain in stock, on average, as long as a refrigerator bought in 1994). Some sources have suggested that the life span of RAC is shortening due to the influx of cheaper and less durable imports, while others contend that the life span of RAC is increasing because of improved design and manufacturing processes. However no reliable sources have been identified that enables any change in the life span of RAC over time to be quantified.

The parameters of the functions and the sources used to develop them are set out in Table 8.

In addition to these sources, where possible, the stock levels and disposal rates estimated by the model have been compared with other sources of information to refine and validate the parameters described above.

Table 9: Parameters of the life span functions for each RAC category

| | Refrigerators | Freezers | Air conditioners |
|--------------------|--|--|---|
| Distribution | Beta | | Normal |
| Lifespan | 10 – 25 years | 13 – 25 years | 10 – 21 years |
| Mean time in stock | 17 years | 18 years | 14 years |
| Source(s) | Commonwealth Government, <i>Major Appliances Material Project</i> , 2001 ABS 4602.2, 2011 Stakeholder interviews | Commonwealth Government, <i>Major Appliances Material Project</i> , 2001 Stakeholder interviews | Energy Efficient Strategies, <i>Status of Air Conditioners in Australia</i> , 2006 Expert Group, <i>Cold Hard Facts 2</i> , 2013 Energy Strategies, <i>ODS and SGGs in Australia</i> , 2008 |

A beta distribution has been chosen to reflect the life span of refrigerators and freezers. A beta distribution is characterised by a mean which is skewed towards the earlier part of the distribution, and a prolonged ‘tail’ towards the end of the distribution. This distribution reflects that these goods are more likely to remain in stock because of their potential for re-use and anecdotal evidence of their longevity beyond manufacturers’ estimations of their life span.

Discussions with stakeholders have confirmed that the practice of re-using air conditioners is close to non-existent. As a result, a normal distribution has been chosen which limits the length of time during which an air conditioner is expected to remain in stock.

Opening stock level

The opening stock level is used as a reference point for the analysis to estimate the growth (or decline) in stock of each category of RAC equipment over time. The year 1994 has been chosen as the reference point for the opening stock level. The assumptions used for the opening stock level are set out in Table 10.

Table 10: Opening stock assumptions, source: Infield (2007), DEHWA (2008), additional analysis.

| | Refrigerators | Freezers | Air conditioners |
|-------|---------------|-------------|--|
| Stock | 8.1 million | 3.3 million | 2.4 million (adjusted upwards by 20% to include evaporative systems) |

Sales forecasts

Sales forecasts for the period 2014 to 2024 are unlikely to have a significant influence on the rate of disposals over the same period. To illustrate this point, using the assumptions of life spans described in the body of the report, an air conditioner purchased in 2014 will be disposed of between 2022 and 2035 (most likely around 2028) which is beyond the timeframe of this analysis. As the life span of refrigerators and freezers is longer than air conditioners, sales of these products in 2014 are unlikely to have an effect on the rate of disposals before 2024.

Sales forecasts do enable the estimation of stock levels in the period 2014 – 2024, which may be useful for analysis in future, and on this basis they have been incorporated into the analysis.

Future sales of RAC equipment may depend on several factors, including market maturity, new unit costs, rate of retirement of old stock and the emergence of new technologies. One common indicator of future sales behaviour for each category of equipment is the saturation of the market, which may be measured by the ownership rate or the average number of units per household. The assumptions that support the sales forecasts in each RAC equipment category are outlined in Table 10 below.

Table 11: Supporting assumptions for sales forecasts

| | Refrigerators | Freezers | Air conditioners |
|------------|---|--|---|
| Assumption | The sum of replacement sales (generated by the analysis), and new sales (1.6 refrigerators per new household) | Sales in the period 2014 – 2024 are estimated to achieve forecast freezer ownership of 0.331 in 2020. | Sales in the period 2014 – 2024 are estimated to achieve forecast ownership of 1.6 in 2024. |
| Source(s) | Australian Bureau of Statistics, catalogue number 3236.0 Additional analysis. | Department of the Environment, Water, Heritage and the Arts, <i>Energy Use in the Australian Residential Sector</i> , 2008 | Additional analysis. |

Approach to estimating composition of air conditioner market

The *Energy Use in the Residential Sector* report provides data on the composition of the air conditioner by type of air conditioner over the period 1966 to 2005. This data is derived from several sources including GfK, Informark and BIS Shrapnel. Data has been selected from the year 2000 as it is just prior to the significant rise in air conditioner sales and hence reflects the composition of the market before it underwent substantial changes.

The most recent available data on the composition of the air conditioner stock in Australia is the *Cold Hard Facts 2* report, which provides an estimate of the quantity of units by type in use in 2013. This data is also derived from several sources including the Department of the Environment import data, Regulatory Impact Statements for air conditioning equipment, interviews with and surveys of air conditioning stakeholders and commercial market research.

Additional data on the composition of air conditioner stock is found in the Australian Bureau of Statistics catalogue number 4602.2. However, discussion with industry stakeholders raised concern with the accuracy of this data as unaware respondents may not have distinguished correctly between the types of air conditioners, particularly window/wall and split system units. As a result alternative sources of data have been used where possible.

It is noted that the *Energy Use in the Residential Sector* report excludes portable air conditioner units. Data from 2000 has been complemented by alternative sources and adjusted to account for the stock of portable air conditioner systems. Similarly, *Cold Hard Facts 2* excludes evaporative systems from its scope. Alternative sources of data from industry participants have been used to estimate the share of evaporative systems in 2013 and the existing data adjusted accordingly.

Approach to estimate material composition of RAC equipment

To estimate the composition of RAC waste by type and quantity of material; the typical weight and composition of each category of RAC - refrigerators, freezers and air conditioners - was estimated by reviewing relevant publicly available literature.

The sources identified were reviewed and assessed for reliability, comprehensiveness, currency and consistency with other sources including industry publications and stakeholder knowledge.

Given the variety of makes and models of RAC equipment, and the existence of changing trends in the size of units and the materials used, there is significant variability in the composition. However, no evidence was reviewed to quantify these sources of uncertainty and so this analysis represents the best approach on the available data.

For air conditioners, the weight and material composition have been determined based on a typical reverse-cycle split system air conditioner, as this is the most common type of domestic air conditioner in use at present. Further accuracy over the composition of domestic air conditioner waste could be gained from identifying the typical weight and composition of other types of air conditioners; however such information was not contained in the sources reviewed for this analysis.

| | Refrigerators and freezers | Air conditioners |
|-----------------------------|---|---|
| Weight | Average of multiple sources (Department of Environment & Heritage, 2001; EPA, 2010; Arcadias Ecolas/RPA, 2008; Nebraska Department of Environmental Quality, 2014). | Average of multiple sources (Department of Environment & Heritage, 2001; Force Technology, 2010). |
| Material composition | Consistent with Infield, 2007 with further information drawn from other sources for smaller categories of materials and adjusted accordingly. | Consistent with Force Technology, 2010, with further information drawn from other sources for smaller categories of materials and adjusted accordingly. |

The average weight and composition proportions for each category of RAC equipment were then applied to the disposals of each category over the period 2014 to 2024 to enable an estimation of the total weight of each material disposed in tonnes per annum.

Hazardous materials

Information on the quantity of hazardous materials present in RAC equipment was primarily obtained from Arcadis Ecolas/RPA(2008) and supported by additional research from EPA (2010), UNEP (2013), Eco3e (2014) and stakeholder discussions.

Appendix C – Data tables

Sales data

(*Indicates estimated/forecast sales)

Table 12: Sales data, source: Table 8

| Year | Refrigerators | Freezers | Air conditioners |
|-------|---------------|----------|------------------|
| 1994 | 587,122 | 109,199 | 170,000 |
| 1995 | 573,465 | 102,223 | 170,000 |
| 1996 | 614,567 | 100,541 | 200,000 |
| 1997 | 652,426 | 102,677 | 215,000 |
| 1998 | 699,418 | 105,640 | 230,000 |
| 1999 | 709,968 | 103,121 | 300,000 |
| 2000 | 706,593 | 107,684 | 580,000 |
| 2001 | 721,207 | 108,918 | 770,000 |
| 2002 | 722,988 | 120,250 | 870,000 |
| 2003 | 793,637 | 132,732 | 850,000 |
| 2004 | 947,580 | 179,758 | 910,000 |
| 2005 | 932,563 | 204,346 | 980,000 |
| 2006 | 1,020,068 | 243,042 | 1,148,647 |
| 2007 | 993,935 | 230,023 | 996,612 |
| 2008 | 1,015,504 | 249,201 | 880,291 |
| 2009 | 996,274 | 207,644 | 1,097,726 |
| 2010 | 1,000,554 | 193,109* | 800,071 |
| 2011 | 1,053,099 | 179,591* | 825,870 |
| 2012 | 1,012,455 | 167,020* | 704,639 |
| 2013 | 995,108 | 156,999* | 682,436 |
| 2014* | 896,586 | 150,719 | 853,044 |
| 2015* | 916,928 | 144,690 | 981,001 |
| 2016* | 937,110 | 138,903 | 1,098,721 |
| 2017* | 958,692 | 133,346 | 1,186,619 |
| 2018* | 988,802 | 128,013 | 1,234,084 |
| 2019* | 1,024,229 | 122,892 | 1,283,447 |
| 2020* | 1,061,900 | 117,976 | 1,334,785 |
| 2021* | 1,095,316 | 113,257 | 1,388,176 |
| 2022* | 1,120,676 | 108,727 | 1,443,703 |
| 2023* | 1,146,405 | 104,378 | 1,508,670 |
| 2024* | 1,168,733 | 100,203 | 1,575,806 |

Disposal rate data

Table 13: Disposal rate data, source: additional analysis

| Year | Refrigerators | Freezers | Air conditioners |
|-------------|----------------------|-----------------|-------------------------|
| 1994 | 264,693 | 93,524 | 51,865 |
| 1995 | 293,269 | 103,848 | 71,185 |
| 1996 | 322,462 | 110,154 | 96,087 |
| 1997 | 351,771 | 114,135 | 126,660 |
| 1998 | 380,878 | 118,388 | 161,758 |
| 1999 | 409,654 | 125,706 | 197,384 |
| 2000 | 438,980 | 138,332 | 226,379 |
| 2001 | 468,377 | 157,152 | 241,054 |
| 2002 | 497,542 | 180,982 | 237,952 |
| 2003 | 524,823 | 207,387 | 220,806 |
| 2004 | 548,355 | 231,723 | 198,512 |
| 2005 | 566,815 | 249,075 | 179,783 |
| 2006 | 579,859 | 255,271 | 169,318 |
| 2007 | 588,092 | 248,961 | 167,867 |
| 2008 | 594,701 | 231,771 | 174,578 |
| 2009 | 601,425 | 207,474 | 189,555 |
| 2010 | 609,942 | 181,091 | 215,916 |
| 2011 | 620,110 | 156,580 | 260,591 |
| 2012 | 632,058 | 136,633 | 331,562 |
| 2013 | 645,444 | 122,213 | 431,048 |
| 2014 | 661,992 | 112,998 | 549,646 |
| 2015 | 682,532 | 108,395 | 669,014 |
| 2016 | 708,846 | 107,266 | 772,730 |
| 2017 | 740,445 | 109,651 | 854,710 |
| 2018 | 775,603 | 115,479 | 916,763 |
| 2019 | 811,882 | 125,184 | 960,119 |
| 2020 | 847,631 | 138,564 | 982,229 |
| 2021 | 880,038 | 154,843 | 981,055 |
| 2022 | 908,311 | 172,086 | 958,703 |
| 2023 | 931,744 | 187,768 | 920,668 |
| 2024 | 949,114 | 199,518 | 875,414 |

Stock

Table 14: Stock data, source: additional analysis

| Year | Refrigerators | Freezers | Air conditioners |
|-------------|----------------------|-----------------|-------------------------|
| 1994 | 8,192,439 | 3,220,839 | 2,445,894 |
| 1995 | 8,470,826 | 3,219,209 | 2,544,709 |
| 1996 | 8,761,123 | 3,209,587 | 2,648,623 |
| 1997 | 9,059,968 | 3,198,116 | 2,736,964 |
| 1998 | 9,376,700 | 3,185,276 | 2,805,207 |
| 1999 | 9,674,302 | 3,162,507 | 2,907,824 |
| 2000 | 9,939,205 | 3,131,651 | 3,261,446 |
| 2001 | 10,188,419 | 3,083,188 | 3,790,391 |
| 2002 | 10,410,249 | 3,021,769 | 4,422,438 |
| 2003 | 10,674,543 | 2,946,426 | 5,051,631 |
| 2004 | 11,068,345 | 2,893,774 | 5,763,118 |
| 2005 | 11,428,670 | 2,848,587 | 6,563,334 |
| 2006 | 11,863,457 | 2,835,900 | 7,542,663 |
| 2007 | 12,262,069 | 2,816,504 | 8,371,407 |
| 2008 | 12,675,643 | 2,833,476 | 9,077,124 |
| 2009 | 13,062,356 | 2,832,959 | 9,985,297 |
| 2010 | 13,444,833 | 2,844,290 | 10,569,452 |
| 2011 | 13,868,786 | 2,866,384 | 11,134,731 |
| 2012 | 14,240,147 | 2,895,623 | 11,507,804 |
| 2013 | 14,579,867 | 2,929,033 | 11,759,190 |
| 2014 | 14,804,517 | 2,965,150 | 12,062,586 |
| 2015 | 15,027,163 | 3,000,069 | 12,374,573 |
| 2016 | 15,243,677 | 3,030,329 | 12,700,564 |
| 2017 | 15,450,174 | 3,053,107 | 13,032,472 |
| 2018 | 15,651,623 | 3,064,953 | 13,349,792 |
| 2019 | 15,852,220 | 3,062,203 | 13,673,119 |
| 2020 | 16,056,725 | 3,041,118 | 14,025,675 |
| 2021 | 16,261,636 | 2,999,064 | 14,432,796 |
| 2022 | 16,462,890 | 2,935,244 | 14,917,796 |
| 2023 | 16,665,754 | 2,851,383 | 15,505,796 |
| 2024 | 16,872,729 | 2,751,582 | 16,206,190 |

Waste composition

Table 15: Waste composition of refrigerators and freezers data, source: additional analysis

| Year | Ferrous metals | Non-ferrous metals | Plastic | Compressor | Motor | Glass | Foam | Foam blowing agent | Oil | Printed Circuit Board | Refrigerant | Other materials |
|------|----------------|--------------------|---------|------------|-------|-------|-------|--------------------|-----|-----------------------|-------------|-----------------|
| 2014 | 24,160 | 2,343 | 10,334 | 7,460 | 1,675 | 926 | 2,769 | 172 | 154 | 59 | 174 | 8,816 |
| 2015 | 24,627 | 2,399 | 10,639 | 7,686 | 1,725 | 955 | 2,814 | 174 | 159 | 60 | 179 | 9,031 |
| 2016 | 25,391 | 2,481 | 11,038 | 7,979 | 1,790 | 991 | 2,896 | 178 | 165 | 62 | 185 | 9,340 |
| 2017 | 26,439 | 2,587 | 11,526 | 8,333 | 1,869 | 1,036 | 3,013 | 185 | 173 | 65 | 193 | 9,739 |
| 2018 | 27,716 | 2,711 | 12,074 | 8,729 | 1,958 | 1,085 | 3,159 | 194 | 181 | 68 | 202 | 10,206 |
| 2019 | 29,163 | 2,847 | 12,648 | 9,140 | 2,051 | 1,135 | 3,329 | 205 | 189 | 72 | 212 | 10,715 |
| 2020 | 30,721 | 2,988 | 13,220 | 9,548 | 2,143 | 1,185 | 3,514 | 218 | 198 | 75 | 223 | 11,244 |
| 2021 | 32,279 | 3,124 | 13,748 | 9,921 | 2,229 | 1,231 | 3,704 | 232 | 205 | 79 | 232 | 11,754 |
| 2022 | 33,744 | 3,249 | 14,214 | 10,248 | 2,304 | 1,270 | 3,884 | 245 | 212 | 82 | 241 | 12,221 |
| 2023 | 35,007 | 3,355 | 14,603 | 10,520 | 2,367 | 1,303 | 4,040 | 257 | 217 | 85 | 249 | 12,618 |
| 2024 | 35,947 | 3,434 | 14,891 | 10,722 | 2,414 | 1,327 | 4,157 | 266 | 221 | 87 | 255 | 12,914 |

Table 16: Waste composition of air conditioner data, source: additional analysis

| Year | Ferrous metals | Plastic | Printed Circuit Board | Refrigerant | Other materials | Copper | Aluminium |
|------|----------------|---------|-----------------------|-------------|-----------------|--------|-----------|
| 2014 | 32,437 | 6,911 | 1,672 | 1,343 | 1,667 | 7,078 | 4,626 |
| 2015 | 39,482 | 8,412 | 2,035 | 1,635 | 2,029 | 8,615 | 5,631 |
| 2016 | 45,603 | 9,716 | 2,351 | 1,888 | 2,343 | 9,951 | 6,503 |
| 2017 | 50,441 | 10,747 | 2,600 | 2,088 | 2,592 | 11,007 | 7,193 |
| 2018 | 54,103 | 11,527 | 2,789 | 2,240 | 2,780 | 11,806 | 7,716 |
| 2019 | 56,661 | 12,072 | 2,921 | 2,346 | 2,911 | 12,364 | 8,081 |
| 2020 | 57,966 | 12,350 | 2,988 | 2,400 | 2,978 | 12,649 | 8,267 |
| 2021 | 57,897 | 12,335 | 2,984 | 2,397 | 2,975 | 12,634 | 8,257 |
| 2022 | 56,578 | 12,054 | 2,916 | 2,342 | 2,907 | 12,346 | 8,069 |
| 2023 | 54,333 | 11,576 | 2,801 | 2,250 | 2,792 | 11,856 | 7,749 |
| 2024 | 51,662 | 11,007 | 2,663 | 2,139 | 2,654 | 11,273 | 7,368 |

Appendix D – Estimated refrigerant gas data for 2014 calendar year

Table 17: Estimated refrigerant gas at end-of-life for 2014 calendar year

| Item | Number of units disposed* | Estimated refrigerant gas per unit at end-of-life [^] | Total estimated refrigerant gas at end-of-life ⁺ | Estimated refrigerant gas recovered at end-of-life [#] |
|---------------------------|---------------------------|--|---|---|
| Refrigerators and freezer | 774,990 | 100 g | 78 t | 30 t |
| Split air conditioning | 549,646 | 1.5 kg | 824 t | 660 t |

Sources: *Appendix C, Table 13: Disposal rate data, source: additional analysis

[^]Based on discussion with industry, refer to report section 2.8 refrigerant gas collectors

⁺Additional analysis: multiplication of number of units disposed by the quantity of refrigerant gas per unit at end of life

[#]Based on estimated refrigerant recovery rates per unit at end-of-life (40% for refrigerators and freezers and 80% for split air conditioners), refer to report section 2.1, Table 1: Estimated refrigerant recovery rates for RAC equipment