



Cold Hard Facts 2020



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1 Executive summary

A significant slowing is evident in the rate of growth of the regulated bank of refrigerants in Australia, in terms of the metric tonnes of refrigerant employed, from 4.3% compound annual growth exhibited in the period 2006 to 2016 to just 1.8% in the three years 2016 to 2019.

This slowing in the rate of growth of the bank, combined with increased use of lower global warming potential (GWP) refrigerants, suggests that the GWP value of the Australian bank of refrigerants may have reached its peak in 2019-20, and with current modelling is expected to decline in the years ahead as the combination of several trends in the refrigeration and air conditioning (RAC) industry accelerate a reduction in the average GWP of the bank.

Slower growth in the metric tonnes of refrigerant in the bank has been driven by a softening of RAC equipment sales in 2018 and 2019 across nearly all major equipment segments, in line with softer economic conditions, and potentially market saturation in some smaller air conditioning equipment segments. Slower growth in the bank of refrigerants is also a product of new equipment designs that require smaller charge sizes to deliver equivalent refrigeration services.

Adoption of natural refrigerants and larger numbers of units in some segments, particularly in self-contained commercial refrigeration, is displacing traditional hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbon (HFCs) applications - even while the stock of equipment is growing.

Adoption of HFC-32 as a lower GWP alternative to HFC-410A in non-ducted split system stationary air conditioning (AC) segments is now a well-established trend, creating a sizeable and fast-growing bank of HFC-32 while capping the growth of the HFC-410A share of the bank. HFC-32 is also starting to make an appearance in larger AC applications including split ducted systems and chillers with charges seen in the market up to 78 kilograms (kg).

Trends observed in 2016 and 2018 of growth in the adoption of natural refrigerants and hydrofluoro-olefin/HFC (HFO/HFC) blends have been confirmed in 2019 with hydrocarbon charges smaller than 150 grams in refrigerated display cabinets being a stand-out example of the rapid rate of change in the sector. HFO/HFC blends are starting to be employed in larger commercial refrigeration cases with charge sizes observed up to 3 kg.

There is some evidence that HFO-1234yf is starting to make a contribution to the transition away from HFC-134a in the automotive mobile air conditioning (MAC) bank however change is still slow with an estimate of less than 5% of the 945,000 new vehicles imported into Australia in 2019 containing HFOs.

Despite a concerted move by major supermarket chains to deploy trans-critical carbon dioxide (CO₂) charged refrigeration systems, the refrigerated cold food chain maintained refrigerant demand for service and charges for new equipment of more than 800 tonnes of HFC-404A with a total of 822 tonnes used in 2019. This level of demand has been very consistent over the last four years.

Emergence and adoption of new refrigerants continues and is resulting in an increasingly diverse bank. Regulatory arrangements in support of a global HFC phase down, and equipment designers' efforts to improve energy efficiency are driving more of the stock of equipment to lower GWP natural refrigerant options and HFOs. In many instances these alternative refrigerants can deliver the same refrigerating capacity with lower energy consumption.

These trends are contributing to slower growth in the regulated bank between 2016 and 2019, and are expected to continue in the decade ahead.

As predicted in earlier editions of Cold Hard Facts, these trends and the evidence suggests that the peak carbon dioxide equivalent (CO₂e) value of the bank has likely been reached in the last 12 months. Improvements in the energy efficiency of the stock of equipment could also see peak energy related emissions reached in the decade ahead, even though the stock of equipment is expected to grow.

2 Introduction

Cold Hard Facts 2020 is the fifth edition of the CHF research series investigating the scale and impacts of the ‘cooling economy’ in Australia.¹ The cooling economy, broadly defined as the total of all goods and services that involve employment of vapour compression refrigeration and heat exchange systems, is a significant fraction of the Australian economy. Direct spending on hardware, consumables and energy, plus employment in the sector, is estimated at more than \$41 billion, or around 2.1% of Australian gross domestic product (GDP) in 2019.²

The cooling economy provides numerous direct and indirect economic, health and social benefits, such as the preservation and transportation of perishable food. In 2018, more than 23 million tonnes of foodstuffs worth \$42 billion based on farm gate values passed through the Australian cold food chain. The production and transport of food, and the cold food chain infrastructure required, is projected to grow strongly in Australia over the next 20 years as export capacities expand, driven by ambitious industry export targets.

While the refrigerated cold food chain is only one part of the total cooling economy, and not the largest, recent studies that have underlined the potential for improvements in design and operation of the cold food chain to mitigate a number of related environmental and economic issues. In 2019, a report prepared by the Expert Group produced estimates of food waste attributable to breaks and deficiencies in the cold food chain in Australia for the first time. Preliminary and conservative estimates put the economic cost of food waste within the cold food chain at a minimum of \$3.8 billion annually at farm gate values. The report estimated greenhouse gas emissions from food waste attributed to sub-par refrigeration technology, practices and processes in the cold food chain at 7.0 million tonnes CO₂-e in 2018, equivalent to about 1.3% of Australia’s annual greenhouse gas emissions in that year.

The value of other services delivered by the cooling economy, such as the maintenance of comfortable conditions in commercial buildings, hospitals and universities, cannot easily be quantified. Cooling services are essential in many situations, and optimal management of the technology that underpins the cooling economy has great potential to deliver significant economic and environmental benefits.

This CHF research series is built upon a techno-economic model, that the Expert Group has been developing for more than a decade of all the equipment employed in the cooling economy in Australia.

The Refrigeration and Air Conditioning (RAC) Stock Model uses a taxonomy of the many different types of refrigerating and air conditioning equipment employed in the economy to manage the mass of data processed through the model. The taxonomy dissects RAC equipment into four main classes and more than 50 different product segments. The main classes of equipment are Stationary Air Conditioning (AC), Mobile Air Conditioning (MAC), the Refrigerated Cold Food Chain (RCFC) and Domestic Refrigeration (DR). The scope and structure of the taxonomy of RAC equipment is explained in *Appendix A, Section 1.1: Taxonomy of a technology*.

Alongside the series of CHF publications, the RAC Stock Model has been continuously improved over the last 15 years, with more than forty other research assignments into aspects of the cooling economy in Australia and overseas.

The depth and integrity of the data now employed and the longevity of the CHF series in Australia has resulted in high degrees of confidence in the outputs of the modelling. Some of the data can be verified by sources such as Australian Bureau of Statistics (ABS), Australian Border Force import statistics, atmospheric monitoring conducted by CSIRO Marine and Atmospheric Research Division, and from RAC industry bodies.

¹ Fourth edition of series, refer CHF 2019 Cold Hard Facts 2019 – Key Developments and Emerging Trends in the Refrigeration and Air Conditioning Industry in Australia, <https://www.environment.gov.au/protection/ozone/publications/cold-hard-facts-2019>

² 5206.0 Australian National Accounts: National Income, Expenditure and Product, Table 3. Expenditure on Gross Domestic Product (GDP), Current prices, Australian Bureau of Statistics, March 2020.

3 The scale of the cooling economy

The RAC Stock Model calculates that RAC services in Australia in 2019 were delivered by more than 57.2 million pieces of equipment (*CHF3 2016, 53.6 million*) employing a refrigerant bank of more than 53,000 tonnes. The stock model calculated that in 2019 Australians spent around \$8.3 billion purchasing and installing new devices across all classes of RAC equipment.

This equipment is estimated to have consumed more than 64.8 gigawatt hours (GWh) of electricity in 2019, or more than 24% of all electricity produced in Australia that year.³ Electricity related greenhouse gas (GHG) emissions and direct emissions to air of around 3,000 tonnes of HFC refrigerant from operating equipment, mean that RAC equipment produced around 61.3 Mt CO₂e of GHGs or approximately 11.5% of Australian national GHG emissions (using the rolling 12 month estimate of emissions to September 2019 of 530.8 Mt CO₂e).⁴

Tables 1 and 2 below list the main metrics produced by the RAC Stock Model for 2019 and 2016.

³ Electricity generated in 2019 was 265,117 GWh, up 1.5% on 2018, *Australian Energy Statistics*, Department of Industry, Science, Energy and Resources, May 2020.

⁴ <https://www.industry.gov.au/data-and-publications/national-greenhouse-gas-inventory-september-2019>

Table 1: Main refrigeration and air conditioning metrics for 2019.

Metric	Units	AC	MAC	RCFC	DR
Share of refrigerant bank	Percent	63%	21%	13%	3%
Size of refrigerant bank	Tonnes	33,200	11,000 ⁽⁴⁾	7,100	1,700 ⁽⁷⁾
Annual usage of HFCs to replace leaks (excl. OEM and charging new equipment)	Tonnes	715	735	906	4
Refrigerant in pre-charged equipment imports ⁽¹⁾	Tonnes	2,328	585	46	14
Estimated stock of equipment	Million units	> 16.1	> 19.3	1.8	20.0 ⁽⁷⁾
Annual electricity consumption ⁽²⁾	GWh	36,150	200 ⁽⁵⁾	19,700	8,800
Share of RAC electricity consumption	Percent	56%	0.3%	30%	14%
Annual GHG indirect emissions	Million tonnes CO ₂ e	28.56	2.94 ⁽⁵⁾	15.80 ⁽⁶⁾	6.97
Share of RAC indirect emissions	Percent	53%	5%	29%	13%
Annual GHG direct emissions (ODS) ⁽³⁾	Million tonnes CO ₂ e	0.39	0.003	0.08	0.00
Annual GHG direct emissions (SGG)	Million tonnes CO ₂ e	2.04	1.40	3.08	0.03
Share of RAC direct emissions	Percent	37%	21%	48%	0.4%
Share of RAC total emissions (not including EOL)	Percent	51%	7%	31%	11%

Notes:

1. HFC substances in pre-charged equipment imports in non-RAC categories is 277 tonnes.
2. The electricity consumption estimate does not take efficiency improvements into account that may have been captured by additions to the fleet of equipment from 2016 to 2019 and is based on assumptions from CHF3.
3. Emissions of ODS are not counted as part of the GHGs reported under the Kyoto Protocol of the United Nations Framework Convention on Climate Change, as they are managed through the Montreal Protocol.
4. An estimated 200 tonnes are refrigerants with a GWP<10.
5. Electricity consumption for MAC is from air conditioners on trains and light rail. Indirect emissions for MAC include indirect emissions from electricity consumption plus emissions from fuel consumption attributed to operating mobile air conditioners on passenger vehicles, trucks, buses and other air-conditioned vehicles.
6. Indirect emissions for the refrigerated cold food chain include indirect emissions from electricity consumption plus emissions from fuel consumption attributed to transport refrigeration.
7. Total stock includes portable and automotive refrigeration. There are now an estimated 8 million devices containing hydrocarbon HC-600a in 2019.
8. Percentages may not total 100 due to rounding.

Table 2: Main refrigeration and air conditioning metrics for 2016.

Metric	Units	AC	MAC	RCFC	DR
Share of refrigerant bank	Percent	61%	21%	14%	4%
Size of refrigerant bank	Tonnes	31,200	10,800	6,900	1,900
Annual usage of HFCs to replace leaks (excl. OEM and charging new equipment)	Tonnes	520	625	821	20
Refrigerant in pre-charged equipment imports ⁽¹⁾	Tonnes	2,359	626	51	32
Estimated stock of equipment	Million units	> 14.4	> 18.2	1.65	19.2
Annual electricity consumption	GWh	30,400	200	19,000	8,500
Share of RAC electricity consumption	Percent	55%	0.3%	31%	14%
Annual GHG indirect emissions	Million tonnes CO ₂ e	30.44	2.96	17.53	7.77
Share of RAC indirect emissions	Percent	52%	5%	30%	13%
Annual GHG direct emissions (ODS) ⁽²⁾	Million tonnes CO ₂ e	0.72	0.01	0.13	0.00
Annual GHG direct emissions (SGG)	Million tonnes CO ₂ e	1.47	1.24	2.91	0.05
Share of RAC direct emissions	Percent	34%	19%	46%	0.8%
Share of RAC total emissions (direct and indirect, not including EOL)	Percent	50%	6%	32%	12%

Notes:

1. HFC substances in pre-charged equipment imports in non-RAC categories is 246 tonnes.
2. Emissions of ODS are not counted as part of the GHGs reported under the Kyoto Protocol of the United Nations Framework Convention on Climate Change, as they are managed through the Montreal Protocol.
3. Percentages may not total 100 due to rounding.

The equipment formats employed across this huge stock of equipment are extremely varied, as is the size of the refrigerant charges in them, from small benchtop drink merchandisers with less than 30 grams of hydrocarbons (HCs), to large chillers with 1,500 kilograms of HFCs cooling enormous structures like airport terminals.

Some of the millions of pieces of RAC equipment introduced to the economy every year will continue to be operational for decades and therefore, even while global agreements are driving the RAC industry towards the use of lower GWP refrigerants, Australia will continue to employ tens of thousands of tonnes of older generation high GWP refrigerants, that will require recovery and destruction, for many years into the future.

Each of the four main classes of RAC equipment, Stationary Air conditioning (AC), Mobile Air conditioning (MAC), the Refrigerated Cold Food Chain (RCFC) and Domestic Refrigeration (DR) is discussed in more detail in the sections that follow.

4 Trends and observations by main equipment class

4.1 Stationary air conditioning

Stationary air conditioning and heat pumps are a broad class of equipment. It includes all forms of stationary equipment using the vapour compression cycle to provide human comfort in buildings and to deliver close temperature control in medical and scientific facilities and in data processing centres. This class includes equipment that can operate in reverse-cycle (heating and cooling) or cooling only and includes heat pumps. Equipment in this class ranges in size from small 2 kW_r (kilowatt refrigeration capacity) portable air conditioners, with a refrigerant charge of less than 600 grams, to large 4,000 kW_r commercial space chillers containing more than a tonne of refrigerant in a single machine. Evaporative air conditioning, that does not use a vapour compression cycle, is not included.

The four major segments and eighteen product categories that make up this class (see *Taxonomy*) account for approximately 63% of the bank of refrigerant in Australia (*CHF3 2016 61%*), or around 33,200 tonnes (*CHF3 2016 31,200 tonnes*), in more than 16.1 million devices.

Stationary air conditioning used more than 38% of all bulk HFC refrigerants imported in 2019,⁵ using an estimated 1,278 tonnes of HFCs for servicing, charging new equipment that was imported without refrigerant or equipment that required additional charge (such as for longer pipe runs), retrofitting existing equipment, and use by equipment manufacturers (*CHF3 2016 1,055 tonnes*).

There are several notable trends in this major class of equipment that will shape the refrigerant bank in the decades ahead.

Single split systems sales including wall hung, cassette, consoles and ducted systems have declined from the all-time peak hit in 2017 of 1.3 million units per annum. Single split system sales in 2019 are estimated at 1.17 million, comprising 1.01 million non-ducted split systems and 156,000 split ducted systems. There were a further 36,000 sales of multi split systems, excluding variable refrigerant volume/frequency (VRV/F) systems and more than 200,000 small self-contained AC including window/wall units and portable AC.

This is the second year in a row of sales of around 1.2 million small and medium stationary AC units, resulting in an estimated total installed stock in Australia of around 13.2 million Small AC and 2.9 million Medium AC devices.

The transition of small split systems to the A2L (low toxicity, slightly flammable) refrigerant HFC-32 is progressing steadily, with year-on-year growth of more than 35% of the installed HFC-32 bank in small split systems. As a result, the aggregate bank of HFC-32 made up more than 21% of the bank employed in non-ducted single split systems in 2019. HFC-32 is displacing the once nearly universal use of the high GWP HFC-410A in this equipment segment.

As a result the HFC-410A bank in the small non-ducted split systems bank showed a slight year-on-year decline towards 10,000 tonnes by the end of 2019. This trend is expected to continue in years ahead, with a five year decrease in the HFC-410A bank in Small AC Split Systems segment of some 40% expected by 2024, to just over 6,000 tonnes as older equipment is taken out of service. The new designs and improved refrigerant containment employed in the HFC-32 charged small AC equipment also means this equipment enjoys extremely low leak rates, ensuring more years of operation at close to optimal charge.

HFC-32 is also starting to make an appearance in larger AC applications including split ducted systems and chillers with charges seen in the market up to 78 kg. In 2019 there were more than 34,000 devices imported

⁵ Bulk import of HFCs in 2019 was 3,310 tonnes.

with a charge greater than 2.6 kg and less than 6.0 kg containing HFC-32. By the end of 2019, there was an estimated bank of more than 3,250 tonnes of HFC-32 across all types of stationary AC.⁶

As HFC-32 is approved for use in more countries, and in larger charge sizes, it is also starting to displace HFC-134a and HFC-410A in some chillers. Scroll chillers, that would previously have used HFC-410A, are now being manufactured with HFC-32 for instance.

HFC-32 is being offered in Large AC with some manufactures offering chillers from 70 kW up to 700 kW, using HFC-32 charges that are thirty percent smaller than the previous HFC-410A charges required. This trend to HFC-32 in chillers with scroll compressor appears to be firmly entrenched in most Japanese based designs that are also offered in Europe.

On the back of the widespread adoption of HFC-32, technology developers are continuing the trend of developing new refrigerant blends for demanding applications. These often incorporate HFC-32 with other HFCs and a portion of one of the newly developed family of very low GWP refrigerants, hydrofluoro-olefins (HFOs). For instance, in 2019 small numbers of chillers with charge sizes ranging from 273 to 2,815 kg were imported pre-charged with HFO/HFC blend R515A, which has a GWP of 386. Another relatively new, lower GWP blend being reported in small and medium sized chillers with charge sizes up to 318 kg is R513A, a HFO/HFC blend with a GWP of 629 that is being promoted as a drop-in replacement for HFC-134a, previously the most widely used HFC in chillers.

The emergence of new blends and new refrigerants is expected to be a continuing trend throughout the next two decades, driven by the need for improved energy efficiency and lower GWP. The increasing diversity of refrigerants in the market will require the RAC workforce to stay up to date with identification of new refrigerants and to understand their properties. Currently the incidence of lower GWP refrigerant alternatives being employed in Australia is relatively small, except for HFC-32, which is well established and being found in a wider range of equipment formats and sizes.

HFOs, that had been predicted to be a rapidly growing portion of the bank, have also slowly begun to be deployed in Australia. Some suppliers are adopting a two-step approach, moving to a Class A1 HFO/HFC blend with around half the GWP of HFC-134a, such as HFC-513A (GWP of 629), while planning the transition to pure HFOs. Every leading chiller manufacturer is currently offering equipment charged with HFOs, with screw chillers available charged with R1234ze and centrifugal chillers using R1233zd. However total sales of pure HFO charged stationary equipment in the period has not been significant and is estimated at less than 5% of sales.

4.2 Mobile air conditioning

Mobile air conditioning (MAC) includes equipment captured in two broad segments of the RAC Stock Model, including Small MAC and Large MAC.

These two segments and the twelve product categories in this class make up the second largest portion of the total bank of working refrigerants, containing approximately 21% of the bank in Australia, or around 11,010 tonnes in more than 19.3 million vehicles of all sorts (*CHF3 2016, 21%, 10,800 tonnes and 18.2 million vehicles*).

Small MAC includes air conditioning equipment in passenger vehicles, light commercial vehicles, trucks and commuter buses which together employed around 93% of the MAC bank in 2019. Large MAC includes equipment found in a diverse range of registered, unregistered and off-road vehicles, such as: larger buses and coaches; locomotives, passenger trains and trams; recreational vehicles and caravans; boats and pleasure craft; aircraft systems; mobile cranes; combine harvesters; and, road construction equipment.

The estimate of the 2019 service usage of 677.4 tonnes is a very robust value, based on six consecutive years of surveying of after market participants, up 14% compared to the five year average of 596.5 tonnes from 2014 to 2018.

⁶ This estimate treats all HFC-32 refrigerant in stock or installed as part of the refrigerant bank.

HFOs that had been predicted to appear in the Australian market soon after release into international markets from around 2011 have, on the basis of available data, begun to be employed in a small portion of new cars sold in 2019.

The majority of vehicles imported by the twenty market leading brands sold in Australia are still primarily reporting HFC-134a charges of pre-charged equipment imports. As HFOs are not reportable, changes to year-on-year sales and changes to numbers of vehicles imported with HFC charged systems have been used to deduce the likely volume of HFOs imported in MAC. Combined with interviews with dealers, the evidence indicates the largest selling brands, such as Toyota, Mazda and Hyundai, have not yet commenced importing systems charged with HFOs into Australia. However, the data does suggest a number of brands with smaller market shares, do appear to have commenced imports of some models with HFO charged MAC, including Japanese auto makers Nissan, Honda and Suzuki, and a number of European brands including BMW and Renault. In total however, the 2019 total volume of HFO imports in MAC would be less than 5% of all refrigerant imported in MAC that year.

Research conducted in the USA and Europe in 2019 appears to confirm that the transition to HFOs in new vehicles is well underway with the large majority of vehicles currently manufactured for those markets now containing HFO-1234yf.

There has been no movement with HFOs or HFO/HFC blends in large MAC in the Australian market. However, there have been some sophisticated and expensive concepts emerging in other markets. For example, a range of modular rooftop units for bus air conditioning was showcased at BusWorld in Rome in 2019. It employed a flammable refrigerant as the primary refrigerant, isolated from the passenger cabin via a glycol secondary loop to deliver comfort conditions to the occupied space. Industry sources confirm there is a lot of interest in charging bus air conditioning with HFO/HFC blend R513A, though none is presently in use in Australia.

There have been no reported movement away from HFCs in locomotive or passenger rail air conditioning in Australia as yet.

4.3 Refrigerated cold food chain

The refrigerated cold food chain (RCFC) includes diverse equipment formats employed in processing, storage, transport and display of perishable foods. This includes cool rooms used inside the farm gate and blast freezers on fishing vessels, at the point of production of food, and continues through numerous refrigerated formats to the point of purchase in retail outlets and hospitality venues.

The RCFC is a diverse group of equipment because of the wide range and scale of applications and situations in which it is employed.

There are a number of notable and fast emerging trends in this class of equipment, including:

- The continuing evolution of advanced refrigeration systems seeking higher efficiency options with lower GWP formats. This trend initially saw the adoption CO₂/HFC two stage cascade systems, although in more recent years this trend has seen accelerated deployment of CO₂ only trans-critical refrigeration systems in new supermarkets and as plant room refurbishments are undertaken.
- In the self-contained refrigerated display cases segments new HC charged system sales continue to take larger market share. While HC refrigerants are not reportable under the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*, inspection of offerings at industry exhibitions during 2019, and anecdotal reports from the supply chain and buyers suggest that sales of HC charged self-contained refrigeration with refrigerant charges smaller than 150 grams could have been as much of 50% of all sales in this category in 2019. The charge size limit in Australia means that manufacturers are focussed on delivering HC charged equipment in the common smaller formats for catering equipment, storage cabinets and two/three door display cabinets. Smaller self-contained display case formats charged with HCs are delivering significant energy efficiency improvements. Major manufacturers are reporting a

concerted move to transition the majority of their designs to HCs. It is reasonable to assume that the large majority of new sales across smaller commercial refrigeration formats will employ HCs within the next two years.

- In some larger formats of self-contained systems where refrigerant charges larger than 150 grams of HCs are required, HFO/HFC blends are being trialled in the market that also deliver improved efficiency and have lower overall GWPs due to the <10 GWP HFO constituents. Blends reported in charges up to 1.5 kg include R449A and R452A in 2019, these blends were used in possibly only 1 or 2% of total display case sales. The 150 gram HC charge threshold was increased in Europe to around 500 grams in self-contained refrigeration in May 2019 so larger HC charged equipment formats are being now developed, tested and deployed in the market and will be ready for deployment into the Australian market. In June 2020, a new edition of AS/NZS 60335.2.89:2020⁷ was released that allows up to 494 grams of R290 in commercial refrigeration appliances (provided the equipment meets the additional requirements of the standard for R290 charge sizes >150 grams and <494 grams). This development is expected to hasten the transition of self-contained commercial refrigeration to HCs with a corresponding dampening effect on HFC-404 in the bank. Another HFO/HFC blend on offer in Europe in this segment is R455A (GWP of 145), that has not been observed in Australia yet.
- Medium sized equipment with remote condensing units, commonly used for walk-in cold rooms (i.e. chillers and freezers) are now offered by European manufacturers to operate on a range of HFO/HFC blends, including R454A, R454C and R455A. While refrigeration compressors are now rated for a variety of blends, the main refrigerant of choice in this sector in Australia is still HFC-404A with suppliers offering HFC-134a as a lower GWP option for medium temperature applications (i.e. chillers).

4.3.1 Transport refrigeration

Road transport refrigeration technology is made up of:

- the transport refrigeration units (TRUs) used on articulated trucks and trailers and on intermodal containers (road or rail) which are described as the trailer/intermodal segment;
- the diesel drive segment largely comprising rigid trucks with a gross vehicle mass of 3 to 8 tonnes; and,
- off-engine vehicle powered refrigeration units used on small trucks and vans.

Trailer/intermodal and diesel drive single temperature units from Europe are imported fully charged, tested and ready to be fitted. These configurations are now rapidly transitioning from HFC-404A to HFO/HFC blend R452A (GWP of 2139) with improved designs and lower refrigerant charges by around 25%. As this market is dominated by two main companies, Thermo King and Carrier Transicold, this transition of new sales is expected to be complete within one to two years.

Diesel powered trailer and truck multi-temperature units are still predominately charged with HFC-404A, with no changes expected to emerge in the Australian market within the next couple of years. Off engine vehicle powered refrigeration units on small trucks and vans transporting chilled goods are mostly HFC-134a.

The fishing fleet still has limited refrigerant options suitable to the conditions and able to be employed in the existing fleet. In 2012 more than 95% of the 52 long distance vessels of between 17 to 28 metres that operate in the northern prawn fishery of Australia were using HCFC-22, with just a few employing HFC-404A. These vessels had typical blast freezing capacity of three tonnes of prawns per day. In the intervening eight years the risk of and cost of HCFC-22 supply resulted in many of the vessels transitioning to HFC-438A (GWP of 2264) which is a HCFC-22 drop-in replacement. Some vessels underwent more expensive equipment upgrades and transitioned from HCFC-22 to HFC-404A with fully welded pipes for improved containment.

⁷ AS/NZS 60335.2.89:2020, *Household and similar electrical appliances - Safety, Part 2.89: Particular requirements for commercial refrigerating appliances and ice-makers with an incorporated or remote refrigerant unit or motor-compressor (supersedes AS/NZS 60335.2.89: 2010).*

Of the 52 vessels operating today, just 8% are operating on HCFC-22, 38% on HFC-438A, 40% on HFC-404A and 13% is unknown.

New designs for larger fishing vessels using ammonia charged refrigeration are starting to enter the market. At time of writing Austral Fisheries is expecting to take delivery of a new 68 metre vessel, the Cape Arkona out of Norway, primarily to fish for Patagonian Toothfish in the Southern Ocean. This vessel has an on-board fish processing and blast freezing capacity of 50 tonnes per day operating on ammonia contained in a dedicated refrigeration plant room. However, like many other types of commercial and industrial equipment, fishing vessels are designed to have very long operating lives. As such, the turnover of the fishing fleet, and thus opportunities for the introduction of new refrigeration systems, is expected to proceed relatively slowly. While this is one example of a fishing vessel operating on a very low GWP refrigerant, the large majority of vessels in the Australian fishing fleet have limited refrigerant options, as smaller vessel size means a dedicated refrigeration plant room is not possible.

4.3.2 Waste in the cold food chain and opportunities for improvement

A recent global and Australian focus on food waste has underlined the importance of the cold food chain in managing a range of social, environmental and economic issues. In 2019, a report prepared by the Expert Group produced estimates of food waste attributable to breaks and deficiencies in the cold food chain in Australia for the first time.⁸ Preliminary and conservative estimates put the economic cost of food waste within the cold food chain at a minimum of \$3.8 billion annually at farm gate values. This figure is made up of:

- 25% of the annual production of fruit and vegetables, or approximately 1,930,000 tonnes worth \$3 billion;
- 3.5% of the annual production of meat, or approximately 155,000 tonnes worth \$670 million;
- approximately 8,500 tonnes of seafood worth \$90 million; and
- 1% of annual dairy production, or approximately 90,000 tonnes valued at \$70 million.

The greenhouse gas emissions from food waste attributed to sub-par refrigeration technology, practices and processes in the cold food chain are estimated at 7.0 Mt CO₂-e in 2018, equivalent to about 1.3% of Australia's annual greenhouse gas emissions in that year. These emissions were equivalent to more than 35% of the total emissions (direct and indirect) that resulted from operation of the cold food chain in the same year (18.9 Mt CO₂-e). These estimates of the emissions resulting from food waste are based on globally accepted estimates of greenhouse gas emissions intensity for the production of various food types.

4.4 Domestic refrigeration

This class of equipment includes both refrigerators and freezers found in every residential kitchen, plus a growing number of portable and vehicle refrigeration systems that are used in caravans, trucks, and as camping systems that can run on low voltage automotive power feeds.

The transition of new domestic refrigerator sales away from high GWP refrigerants is effectively complete with 99% of domestic refrigerators and freezers sold in 2019 containing HC refrigerant. Just 10.8 tonnes of HFC-134a was imported in domestic refrigeration systems in 2019, almost entirely in very low charge portable and vehicle refrigeration systems, compared to a peak of 139 tonnes in domestic refrigeration systems in 2008. There are no signs of these very low charge portable and vehicle systems (<65 grams of HFC-134a) transitioning away from HFC-134a.

As a result of the comprehensive transition of new sales to HC charges, the proportion of hydrocarbon charged domestic refrigerators and freezers in the stock of equipment has grown strongly since 2012, with

⁸ <https://www.environment.gov.au/protection/ozone/publications/waste-study-cold-food-chain-improvement-opportunities>

an estimated 40% of the stock (~8 million devices) containing hydrocarbon HC-600a in 2019. As older stock is removed from service and replaced, the proportion of HC charged domestic refrigeration is expected to be greater than 50% of the stock of this equipment segment before the end of 2021.

Service consumption of HFCs has continued to decline in this sector as older equipment charged with HFCs becomes increasingly un-economical to service or repair.

In later editions of the Cold Hard Facts research series, the Domestic Refrigeration Class of equipment will be amalgamated into the Refrigerated Cold Food Chain class, simplifying the CHF taxonomy to just three major equipment Classes.

5 The refrigerant bank

The common denominator of all vapour compression air conditioning and refrigeration is that it employs a thermal media; the working refrigerants that are the medium for transferring heat. The sum of all refrigerant contained in RAC equipment is referred to as 'the bank' of working refrigerants.

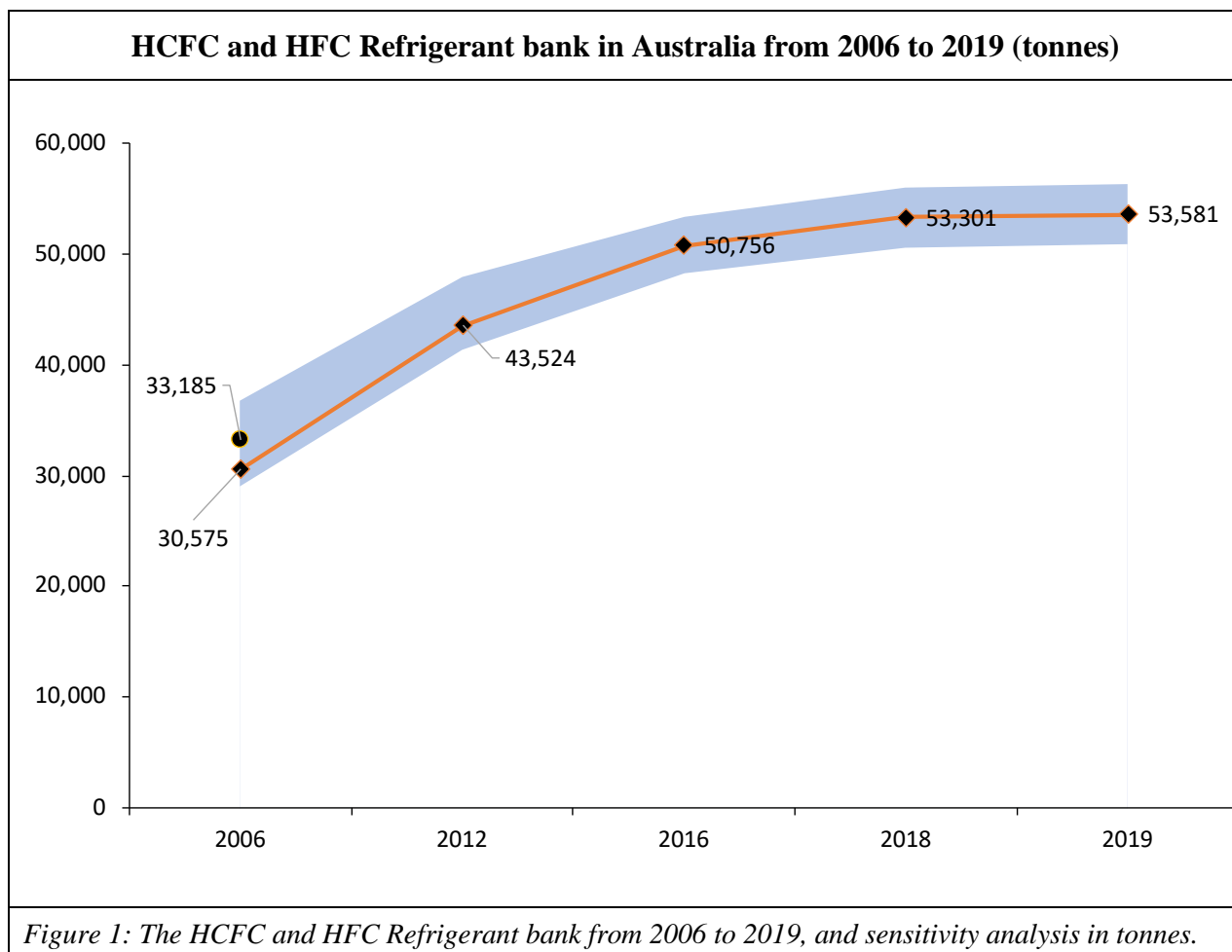
Over the past century, as the RAC industry has developed and expanded to become one of the cornerstone technologies of modern society, the nature of the bank has also evolved. Originally starting with common compounds such as ammonia and methyl chloride, today the bank is populated by dozens of synthetic and natural refrigerants with varying properties suitable for different applications.

As shown in *Figure 1*, the total refrigerant bank of HCFCs and HFCs in Australia has grown strongly since this research series commenced in 2006, increasing more than 61% in the period. This strong overall growth in the refrigerant bank Australia has experienced since 2006 has been largely, but not entirely, as a result of more than a decade of strong sales growth of small and medium domestic and commercial air conditioning systems (<25 kW), up to the peak in sales reached in 2017.

This trend was supported by steady falls in the price of small split AC, combined with increasing marketing budgets invested in branding and advertising by the leading manufacturers since the turn of the century. The growing community-wide acceptance of and dependency on AC, and widely held expectation of AC comfort in all forms of buildings, was reinforced by changing climatic conditions that have seen five of the hottest years ever recorded in the last seven.

The near comprehensive adoption of mobile AC in all types of vehicles, and growth in the passenger and light commercial vehicle fleet of more than 50% since the year 2000, has also contributed strongly to growth of the bank.

During the same period, Australia's increasing food exports have driven greater investments in refrigeration systems in agriculture and an expansion of the refrigerated cold food chain in Australia. This sector is also directly affected by hotter temperatures.



(Sources: CHF1, CHF2 and CHF3 RAC Stock Models)

Notes:

1. The band provides sensitivity analysis with the 2006 value (+20%, -5%), 2012 value (+10%, -5%), 2016 and 2018 values (+5%, -5%). In CHF2 the authors concluded that the 2006 bank was likely to have been underestimated by no more than 10%, the value of 33,185 tonnes represents higher estimate.

The total bank in 2019 is estimated at approximately 53,581 tonnes (*CHF3 2016, 50,756 tonnes*). This is the slowest rate of growth in the bank since the research series began in 2006.

Using the starting point of 33,185 tonnes in 2006, the regulated bank grew by around 53% between 2006 and 2016, equivalent to a compound annual growth rate of 4.3% over the period. However, from 2016 to 2019 the bank of HFCs and HCFCs has only increased slightly more than 5.5%, achieving a compound annual growth rate of just 1.8%.

This shows the slowdown in the rate of growth of HFCs in the bank, as sales of small split AC systems have stabilised and then declined, and as non-HFC alternatives have taken more market share in some equipment segments (particularly in domestic refrigerators and self-contained commercial refrigeration).

Notably, additional to large ammonia charged systems, there is estimated to be slightly more than 1,000 metric tonnes of non-HFC natural and low GWP refrigerants with a GWP<10 in use in the stock of equipment in 2019, an increase of more than 13% on just one year earlier. While this low GWP refrigerant bank is only equivalent to slightly less than 2% of the metric tonnes employed in the bank of regulated refrigerants, it is growing rapidly and is taking market share from HFCs. Efforts to improve the quality of data about the rate of adoption of these unregulated and therefore unreported refrigerants are underway and monitoring will continue.

Having successfully implemented an international phase out of ozone depleting refrigerants, international governments and the refrigerants industry have started a phase down of HFCs, including refrigerants, to further reduce emissions. This is resulting in increasing diversity in the types of refrigerants employed in equipment as a fourth generation of refrigerants is developed and tested, and existing natural refrigerants find wider applications.

5.1 Constituents of the bank, GWP and CO₂e

The main species of refrigerants in use today, described below in order of proportion of the bank they comprise, are:

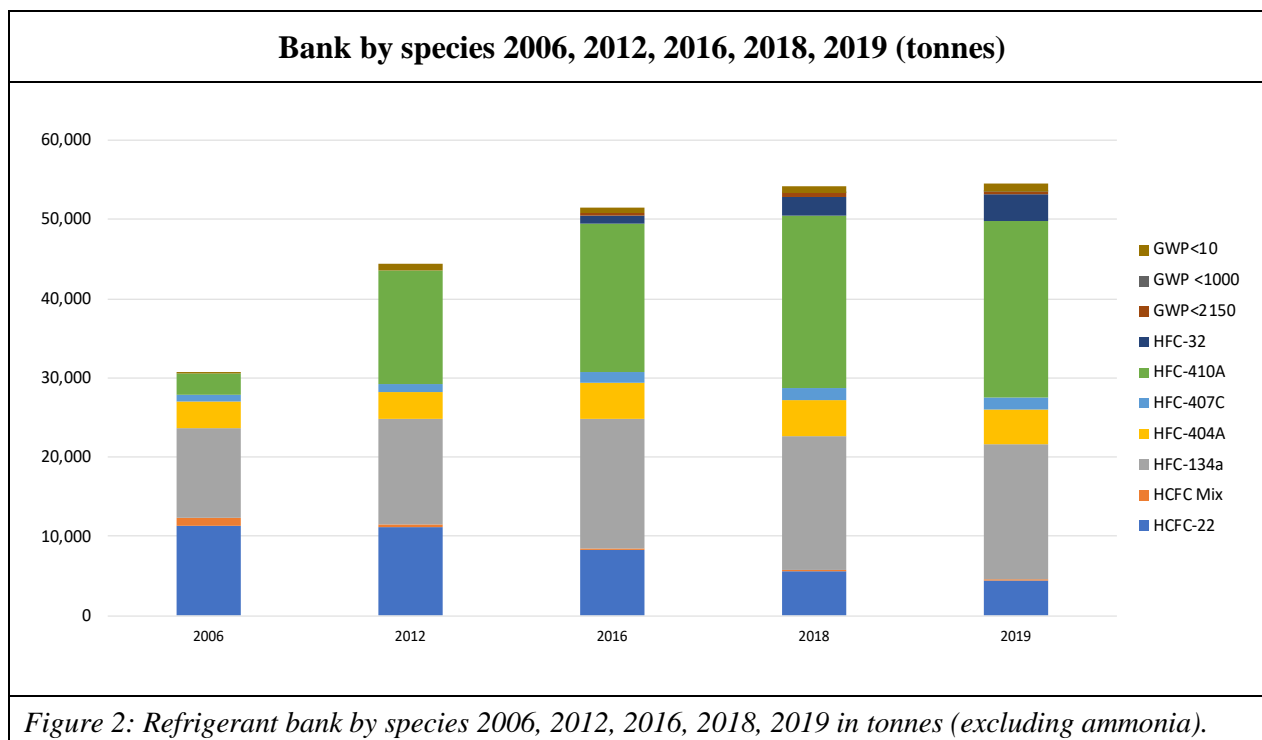
- HFCs comprise 48,500 tonnes, or 90% of the bank, up from 83% in 2016. The half dozen most common HFCs that make up the majority of the bank have high GWP values, ranging from 675 for HFC-32, to 3922 for HFC-404A. HFCs are now subject to an international agreement to phase down their production and consumption gradually from 2019 towards a 2036 target capped at 15% of recent levels of annual global production and consumption;
- HCFCs and CFC make up 4,700 tonnes or 8.7% of the bank (down from 16% in 2016). These were once the most common species of refrigerant in use. HCFCs are being phased out of production under the Montreal Protocol, an agreement established in 1987. Significant volumes, particularly of HCFCs, are still employed in the stock of equipment and, due to the long life of some types of equipment, are expected to persist in the economy and the environment well towards the end of the 2020s;
- The bank of natural refrigerants in commercial refrigeration and mobile applications in 2019 is estimated at around 1,000 tonnes (up quite strongly from 700 tonnes in 2016). Natural refrigerants are a group of refrigerants including ammonia, hydrocarbons and CO₂, that have very low or zero GWP, but that may have other properties, such as flammability, toxicity or requirements for higher operating pressures, that limit their use in some applications⁹. There is a further estimated 5,000 tonnes of ammonia in use in the cold food chain, the vast majority of which is in large chilling, blast freezing and ice making systems in the primary and secondary stages of the cold food chain, and large cold storage distribution centres. These ammonia refrigerants are not included in the estimate of the bank in 2019 as illustrated in *Figure 2*.
- HFOs are the newest generation of synthetic refrigerants that, in most cases, are mildly flammable, but exhibit the properties of thermal stability and non-toxicity that HFCs provide, while also having very low GWPs (the GWPs of HFO-1234yf and HFO-1234ze are 5 and 1, respectively).¹⁰ HFOs are entering into service internationally, initially in new motor vehicles, and chiller manufacturers are offering models that employ HFOs due in part to the energy efficiency gains they deliver. In 2019 there was no significant volume of HFOs¹¹ in use in equipment in Australia.

The effects of regulation, the introduction of new generations of gases, changing consumer demand and industry trends have all contributed to the current make-up of the refrigerant bank in 2019.

⁹ For further clarification on refrigerant properties, classifications and potential for replacement refer to 'AS/NZS ISO 817: 2016 Refrigerants - Designation and safety classification'; 'AS/NZS: 2016 (ISO 5149-1:2014, MOD) Refrigerating systems and heat pumps - Safety and environmental requirements'; and 'IEC 60335-2-89, Household and similar electrical appliances – Safety'.

¹⁰ IPCC Assessment Report 5.

¹¹ HFOs are not defined as controlled substances under the Ozone Protection and Synthetic Greenhouse Gas Management Act 1989, and therefore are not reportable in the same way that HFCs and HCFCs are at the point of importation. Future data on HFOs in the bank may not be available with the same accuracy that the Department of Agriculture, Water and the Environment data on imports of HFCs and HCFCs currently allows (i.e. pre-charged equipment data).



The effect of the rapid adoption of small and medium AC, and the shift away from HCFCs, can be seen in the slow decline of HCFC-22, once the largest single component of the bank, coupled with the rapid growth of HFC-410A between 2006 and 2018.

The move from HCFC-22 to HFC-410A as the predominant refrigerant charge in small and medium stationary AC started around 2005. This occurred around the time small and medium AC sales first passed more than one million units a year in Australia; a figure that continued to climb to more than 1.3 million units sold in 2017. The decade-long million-plus annual unit sales has built a stock of more than 10 million HFC-410A charged pieces of equipment, containing a bank of more than 22,000 tonnes of HFC-410A, representing more than 40% of the entire bank.

This growth in HFC-410A from just 9% of the bank (2,800 tonnes) in 2006 means that HFC-410A is now the largest single component of the bank, surpassing HFC-134a now at just under 17,000 tonnes. The HFC-410A bank is now more than four times larger than the declining bank of HCFC-22 that it was introduced to replace.

HCFC-22 as a proportion of the total bank has declined from 37% in 2006 to 8.4% in 2019.

Previously HCFC-22 was the refrigerant of choice in air conditioning applications. In absolute metric tonnes employed it peaked before 2012 when HCFCs made up nearly 30% of the bank. In what is quite a sharp fall, the bank of HCFCs has reduced by more than 9,000 tonnes from that high point, a drop of more than 66%, in the last 10 years.

This was a predictable outcome due to the age of the stock of HCFC-22 charged equipment employed in Australia, and the accelerated phase out of HCFC-22 adopted by Australia in the mid-1990s under its commitment to the Montreal Protocol. In 2016 Australia's HCFC import cap stepped down from 10 ODP tonnes to just 2.5 ODP tonnes (equivalent to around 45.5 metric tonnes of HCFC-22 per annum), before the final phase out of HCFC imports in 2030.

This phase out of bulk imports was coupled with a ban on imports of most HCFC-22 pre-charged equipment that commenced in July 2010. The import of space chillers charged with HCFC-123 continued until the end of 2015.

Despite the ban on import and manufacture of HCFC charged equipment, small quantities of HCFC pre-charged equipment are still able to be imported under special exemptions, mainly as replacement parts for condensing units to match evaporators of air conditioning units already installed.

Expert Group analysis indicates that the tail of greatly reduced HCFC-22 bulk imports until the end of 2029 will not be sufficient to meet demand for service and repair of the remaining HCFC charged equipment. Forecast service demand for HCFC-22 can only be met by recovering and recycling much of the remaining bank of HCFC-22 as older equipment is retired. Data available from Refrigerants Reclaim Australia (RRA) indicated that nearly all HCFC-22 recovered by contractors during service or from end-of-life equipment is being reconditioned and reused. An increase in the use of effective 'drop-in' replacements is also being reported and may relieve pressure for the reuse of the steadily declining bank of HCFC-22.

Additional HCFCs, above the import cap, will be required for service and maintenance until at least 2025. In the case of HCFC-123, which is employed in long lasting, large, and expensive chillers, the service requirement is likely to continue for at least another decade.

The effect of the decreasing supply and increasing prices for HCFC-22 since 2012 has created an active recycling industry to supply reconditioned HCFC-22 that provides equipment owners an option to get the longest possible operating life out of their equipment.

The HCFC bank will continue to decline as some of the many smaller HCFC charged air conditioning units that were installed between 10 and 25 years ago are retired. However, the rate of recovery, reconditioning and then reuse of HCFC-22 in larger, longer life equipment, will become a significant driver of changes to the HCFC bank, and its overall rate of decline in the decade ahead. Given that there is an active market for reconditioned HCFC-22, it would be reasonable to expect the rate of decline in the HCFC-22 bank to slow as recovery rates increase, with the last generation of HCFC-22 charged equipment, installed as late as 2011 and 2012, potentially maintained on 100% recycled and reconditioned refrigerants into the early 2030s.

However, predicting the future rate of change in the bank of HCFCs is now becoming more complicated as market intelligence suggests an increasing amount of unreported HCFC-22 recovery and reuse by contractors, the relative cost and benefits of maintaining older equipment, and the changing market prices for recycled HCFC-22.

After HFC-410A, HFC-134a is the second most abundant refrigerant in the 2019 bank, growing steadily at around 3% per annum up to 2016, at which point it constituted some 32% of the bank. New refrigerant uptake has seen HFC-134a decline marginally since 2016 to make up 31.6% of the total bank in 2019.

HFC-404A saw strong growth in overall tonnes between 2012 and 2016, increasing by more than 1,200 tonnes, or more than 30%, to reach 4,550 tonnes, reaching 9% of the total bank in 2016. Since that time, it has declined slightly with now an estimated 4,500 tonnes in 2019 representing just 8.2% of the bank.

The rapid adoption of HFC-32, primarily in small and medium sized stationary AC applications, saw total volumes grow strongly from nearly 2,300 tonnes in 2018 to more than 3,200 tonnes in 2019. This growth is occurring largely at the expense of the much higher GWP HFC-410A. HFC-32 made up 6% of the bank in 2019, up from just 4% in 2018. Adoption of HFC-32 across a wider range of equipment formats is expected to further accelerate the rapid growth of this HFC in total tonnes, and as a proportion of the bank.

Mostly as a result of having similar refrigeration characteristics as HCFC-22, which it is sometimes used to replace, the bank of HFC-407C reached approximately 1,300 tonnes in 2016, having grown steadily from around 700 tonnes in 2006, increasing its proportion to 2.8% of the bank. By 2019 HFC-407C had grown to more than 1,500 tonnes although was still only 2.8% of the overall bank.

The table below contains the data from which *Figure 2* was produced. The tabulated data of the bank by species notably shows the emergence in 2016 of HFC-32 as a component of the overall bank. HFC-32 with a GWP of 675, as compared to HFC-410A with a GWP of 2088, is expected to cap the overall GWP intensity of the refrigerant bank as it becomes the most common refrigerant employed in the extensive stock of small AC.

Table 3: Refrigerant bank 2006, 2012, 2016, 2018 and 2019 by mass in tonnes and share in percent.

	2006 ⁽¹⁾		2012		2016		2018		2019	
	Tonnes	Share	Tonnes	Share	Tonnes	Share	Tonnes	Share	Tonnes	Share
HCFC-22	11,280	37%	11,227	26%	8,283	16%	5,605	10.9%	4,475	8.7%
HCFC Mix	1,000	3%	201	0%	217	0%	199		190	
HFC-134a	11,389	37%	13,432	31%	16,343	32%	16,803	31.5%	16,933	31.6%
HFC-404A	3,412	11%	3,306 ⁽⁴⁾	8%	4,547	9%	4,560	8.6%	4,501	8.4%
HFC-407C	711	2%	1,017	2%	1,336	2.6%	1,492	2.8%	1,519	2.8%
HFC-410A	2,783	9%	14,341	33%	18,660	37%	21,893	41.1%	22,262	41.5%
HFC-32	0	0%	0	0%	1,035	2.0%	2,286	4.3%	3,245	6.1%
GWP<2150	0	0%	0	0%	336	0.7%	432	0.8%	418	0.8%
GWP <1000	0	0%	0	0%	0	0%	31	0.1%	37	0.1%
Total HCFCs and HFCs	30,575	100%	43,524	100%	50,756	100%	53,301	100%	53,582	100%
GWP<10	100	-	799	-	737	-	902	-	1,018	-

(Sources: Expert Group Data and Analysis, CHF1, CHF2 and CHF3 RAC Stock Models)

Notes:

1. The 2006 values in the table are estimates from “*ODS and SGGs in Australia: A study of end uses, emissions and opportunities for reclamation*”, prepared by Expert Group in 2008.
2. Some CFCs are still present in the bank, for example in some very old domestic refrigerators, however are not included in the above table in their own right and are included in the estimate of HCFC-22. Some relatively small quantities of HCFC blends used in air conditioning applications are also counted as HCFC-22.
3. The category ‘GWP<2150’ comprises a variety of blends including HFC-407F, HCFC-22 replacement refrigerants, and emerging HFO blends such as HFC-448a and HFC-449a which are starting to be used for low temperature commercial refrigeration applications.
4. This value is the published CHF2 bank of HFC-404A. Based on CHF3 methodology the bank of HFC-404A in 2012 would be higher. Since CHF2 the number of walk-in cold rooms has been revised upward and the stock and bank value has been revised based on improved information. For example, the stock of self-contained refrigeration display cabinets and walk-in cool rooms were revised upward.
5. The GWP<10 substances listed in the above table represents only the bank in those applications that have transitioned from prior generations of equipment employing HCFCs and HFCs and moved to low or zero GWP refrigerants and does not include ammonia systems.

5.2 Retirement and recovery

In 2019 RAC equipment containing an estimated 2,340 tonnes of residual refrigerant reached the end of its useful life. It should be noted that the majority of equipment that is retired would not be fully charged, and the Expert Group RAC stock model calculates various rates of partial charge for retiring equipment. More than 80% of the refrigerant estimated to have still been in end-of-life (EOL) equipment in 2019 would have been in stationary equipment types including domestic refrigerators and freezers, stationary air conditioners and self-contained equipment employed in the refrigerated cold food chain. An unknown portion of this

refrigerant is likely to have been recovered by contractors for reuse, particularly if it was HCFC-22 for which an active reclamation market is in place.

The RAC Stock Model assumes end-of-life residual factors for each product category, for example split ducted air conditioners are estimated to retain 80% of their original charge at retirement. Studies of EOL motor vehicles indicate that average charges of MAC at retirement are around 2/3rds of the original charge. The RAC Stock Model uses a residual charge of 66% for EOL MAC in vehicles. Refer to *Appendix B Table 1: Technical characteristics by product category*, for end of life factors and assumptions. Further work in this area is required to improve confidence in calculations of refrigerant in EOL equipment.

Approximately 486 tonnes of refrigerant was recovered by Refrigerant Reclaim Australia (RRA) in 2019 comprising 3.1 tonnes of chlorofluorocarbons (CFCs), 27.6 tonnes of HCFCs, 381.9 tonnes of HFCs and 3.8 tonnes of other substances. Of this 69.6 tonnes was retained for reclamation while the rest was destroyed. Refrigerant recovered by the RRA program is recovered from both EOL equipment and from equipment during service where refrigerant that is not suitable for reuse is removed and replaced with new refrigerant.

Maximum imports of HCFCs for 2016 to 2019 are capped at 2.5 ODP tonnes per annum, which equates to 45.5 metric tonnes of HCFC-22. The additional usage of HCFCs reported in those years of 210, 179, 117 and 93 tonnes of HCFC refrigerants is possible because the material employed above the import cap has been reclaimed and reconditioned to AHRI 700 standard so that it can be resold. There would be an additional but at present unknown amount of HCFC-22 recovered by contractors and re-used 'in the field'.

Overall however the noticeable decline in total tonnes of HCFC-22 reported as sold between 2016 and 2019 indicates a market in general decline, a trend that will be watched closely in subsequent years.

6 Refrigerant imports and usage

There are two means by which the bank of working gas in Australia grows:

- via imports of equipment pre-charged with a refrigerant gas, referred to as pre-charged equipment (PCE) imports; and,
- via imports of bulk gas, where the bulk gas is used for charging new equipment that has been manufactured in Australia, or it is used for charging equipment that has been imported without a refrigerant charge, or applications with longer than usual pipe runs requiring additional charge.

This section analyses PCE and bulk gas imports, and then examines the market dynamics for bulk gas as it is broken down into smaller lots and distributed (sold) into the supply lines for servicing the stock of existing equipment and charging new equipment.

Natural refrigerants, ammonia, CO₂ and hydrocarbons are not scheduled substances under the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* and are discussed separately in *Section 8*. Hydrofluoro-olefin refrigerants are not classified as scheduled substances which are also ingredients used in HFO/HFC blends are briefly discussed at the end of this section (*Section 6.4 Hydrofluoro-olefin refrigerants*).

6.1 *Pre-charged equipment imports*

By volume of gas imported in pre-charged equipment, all major equipment segments were lower in 2019 compared to 2018. Approximately 3,230 tonnes of HFCs were imported in more than 2.6 million pieces of pre-charged equipment in 2019.

Import volumes of HFCs were down more than 12.5% compared to 2018, and more than 13.2% compared to the all-time high of 3,720 tonnes in 2017. In terms of equipment stocks, 2019 imports at 2,671,541 pieces was down 11.9% on 2018 and more than 15.5% on 2017 imports.

Volumes of HFCs imported in Stationary AC, the most populous equipment segment, were down by nearly 20% on the prior year in 2019. This was driven by the decline in the number of sales of small split systems and because HFC-32 charged split systems have a smaller refrigerant charge compared to earlier models employing HFC-410A. Notably in this overall decline in the total volume of HFCs the volume of HFC-410A declined by more than 35% year-on-year from 2,079 tonnes to 1,371 tonnes, while the volumes of HFC-32 increased by 35% from 654 tonnes to more than 886 tonnes.

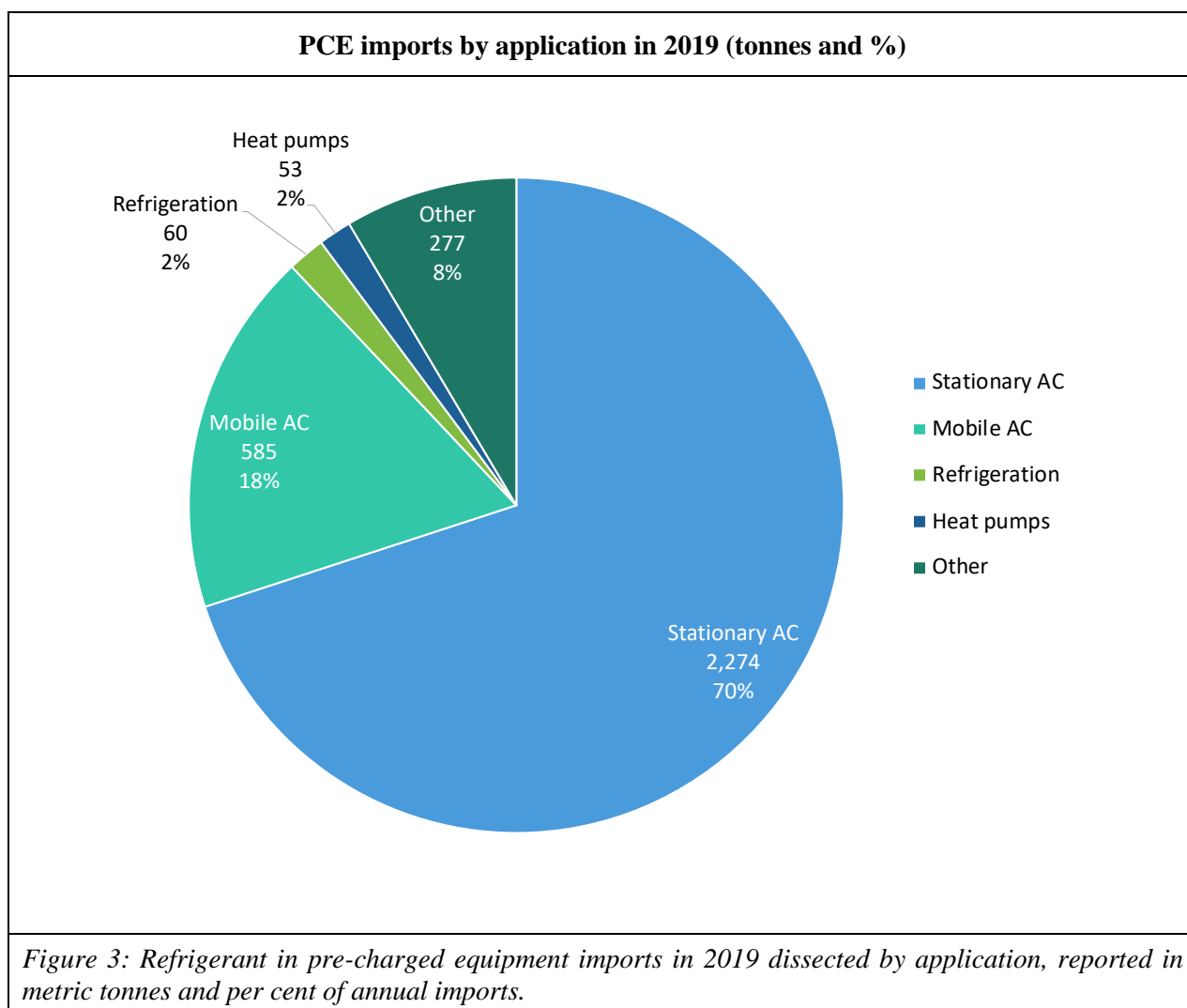
Similarly, the volume of HFCs imported in Mobile AC was down by 14% in 2019 as compared to 2018 on the back of lower volumes of vehicle imports. The Federal Chamber of Automotive Industries reported 2019 sales of new vehicles at 1,062,867, a 7.8% decrease on the prior year, and the lowest number of new car sales recorded since 2011.¹² A small part of the decrease in imported gas volumes in MAC could be the first signs of the adoption of HFOs in MAC, however because HFOs are not reportable, there is only circumstantial evidence available pointing to this conclusion at this point. If HFO replacement of HFCs in MAC is the cause of some of the decline in MAC volumes, this trend should be able to be confirmed in the coming years.

Refrigerant volumes imported in pre-charged commercial refrigeration equipment were down by 9% with the number of pre-charged commercial refrigeration equipment imported containing HFCs down by more than 34% year-on-year to 71,386 units in 2019. In this segment at least part of that decline could be attributed to the continuing trend of self-contained commercial refrigeration to employ natural refrigerants, specifically HC.

These consistent declines across all the major equipment segments could potentially be, at least in part, attributed to a softer economy in 2019, and lower consumer and business confidence. At the same time, at least in the case of some commercial refrigeration segments and in medium and large chillers, where Australia still has a viable and competitive manufacturing sector, some of the import declines may be due to more domestic manufacturing.

While a relatively small category in terms of equipment numbers at 67,524 pieces imported in 2019, heat pumps across all applications, space and water heating and clothes drying, bucked the trend, growing 5.8% year-on-year to maintain a long term trend that have seen annual imports grow by more than 200% since 2015.

¹² <https://www.fcmai.com.au/news/index/view/news/600>



(Source: DAWE 2020)

Notes:

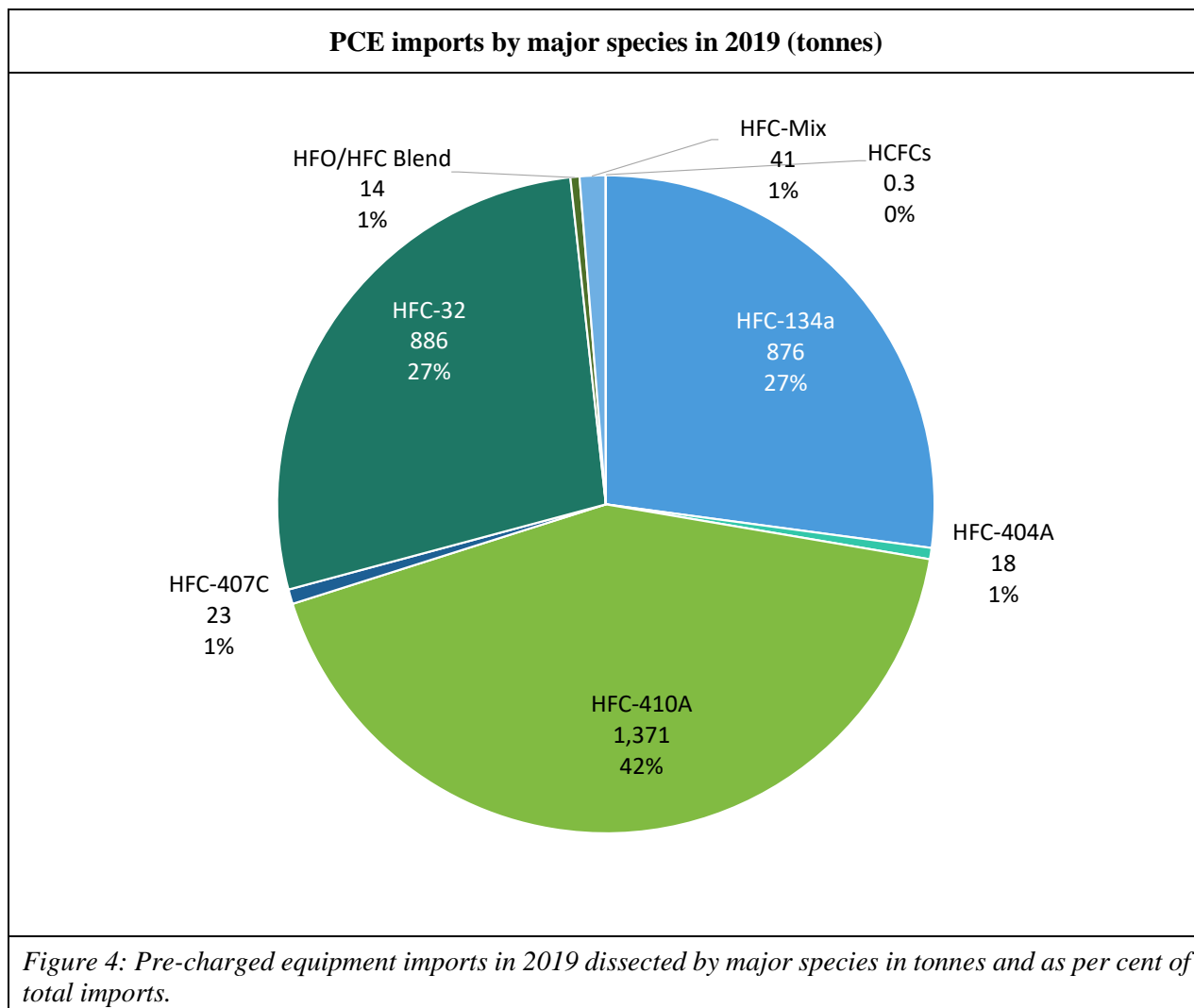
1. Stationary AC includes domestic and commercial categories.
2. Mobile AC includes PCE category motor vehicle, watercraft or aircraft air-conditioning and refrigeration.
3. Refrigeration includes domestic and commercial refrigeration categories.
4. Other includes aerosols, components, consumer goods, fire protection and scientific or electrical equipment and switchgear.

While MAC equipment imports are approaching stationary AC import numbers, the much greater contribution to imported HFCs of pre-charged stationary AC is a result of the larger average charge sizes in stationary AC systems, which range from an average charge of 1.6 kg (*CHF2 1.7 kg*) in residential systems to average charges of greater than 5 kg in small commercial systems. By comparison the average charge in all MAC imported in 2019 was 570 grams (*CHF3 2016, Stock Model 620 grams*).

The dominance of stationary AC in PCE imports is reflected in the mix of refrigerant contained in those imports in 2019, with the high GWP refrigerant of choice for stationary AC for the last decade, HFC-410A, still dominating the mix with 1,371 tonnes in PCE making up 42% of PCE refrigerants in 2019.

At the same time HFC-32 pre-charged equipment made up 27% of imports by refrigerant mass (*2018, 19%*), the very large majority of which was imported in small split AC systems.

HFC-32 charged stationary AC devices in the stock of equipment now number more than 2.8 million containing more than 3,250 tonnes of HFC-32¹³ with more than 886 tonnes being added to the HFC-32 bank in 2019.



(Sources: DAWE 2020)

The growth of the HFC-32 share of PCE imports (from nearly zero in 2012) can be seen in *Figure 5*. HFC-32 is expected to aggressively take market share from HFC-410A charged equipment until HFC-32 becomes the dominant refrigerant imported in the stationary AC segment during 2022-23. The use of HFC-32 in medium AC applications, a trend that commenced in the last two years, is expected to grow strongly over the next five years.

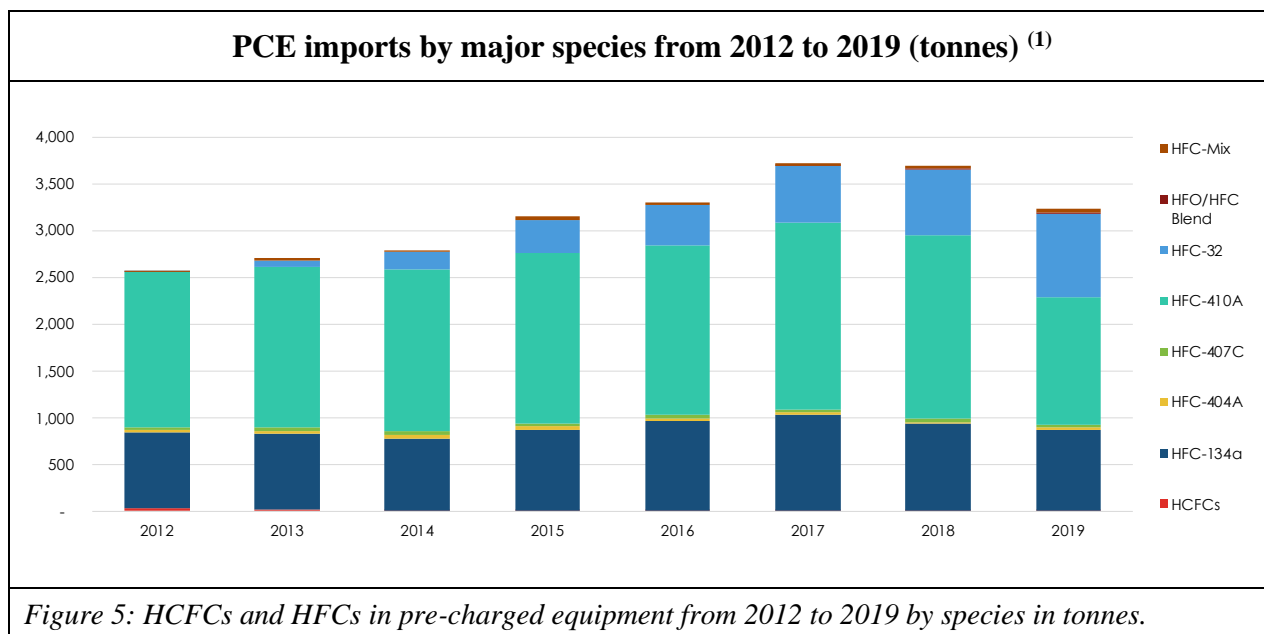
A portion of the 32 tonnes of HFC-410A and HFC-407C imported in 2019 that was contained in chillers with a charge greater than 12 kg is expected to migrate to HFC-32 and to HFO blends in the years ahead.

HFC-134a has maintained a relatively steady share of import volumes in PCE during the last decade, as can be seen in *Figure 5*. A rise in HFC-134a pre-charged imports was discernible in 2017 and 2018 as vehicle manufacturing in Australia declined to zero and all new vehicles sold were imported. However, the rising PCE imports were only replacing what was previously imported as bulk gas for use by domestic vehicle manufacturers.

¹³ Based on pre-charged equipment imported until the end of 2019 calendar year.

PCE imports containing HFC-134a are expected to show steady declines by the mid-2020s:

- A portion of vehicle imports are predicted to migrate to HFO-1234yf and insignificant volumes of CO₂ refrigerant;
- A portion of the 60 tonnes of HFC-134a currently imported in chillers will migrate to HFO-1234ze, HFO-1233zd, HFO-1336mzz, HFO/HFC blends such as R513A and R515A, and HFO blend R514A¹⁴;
- Small and medium commercial refrigeration will continue the strong trend of migration to hydrocarbon and HFO/HFC blends including R448A, R449A, R450A, R452A, R455A and others.

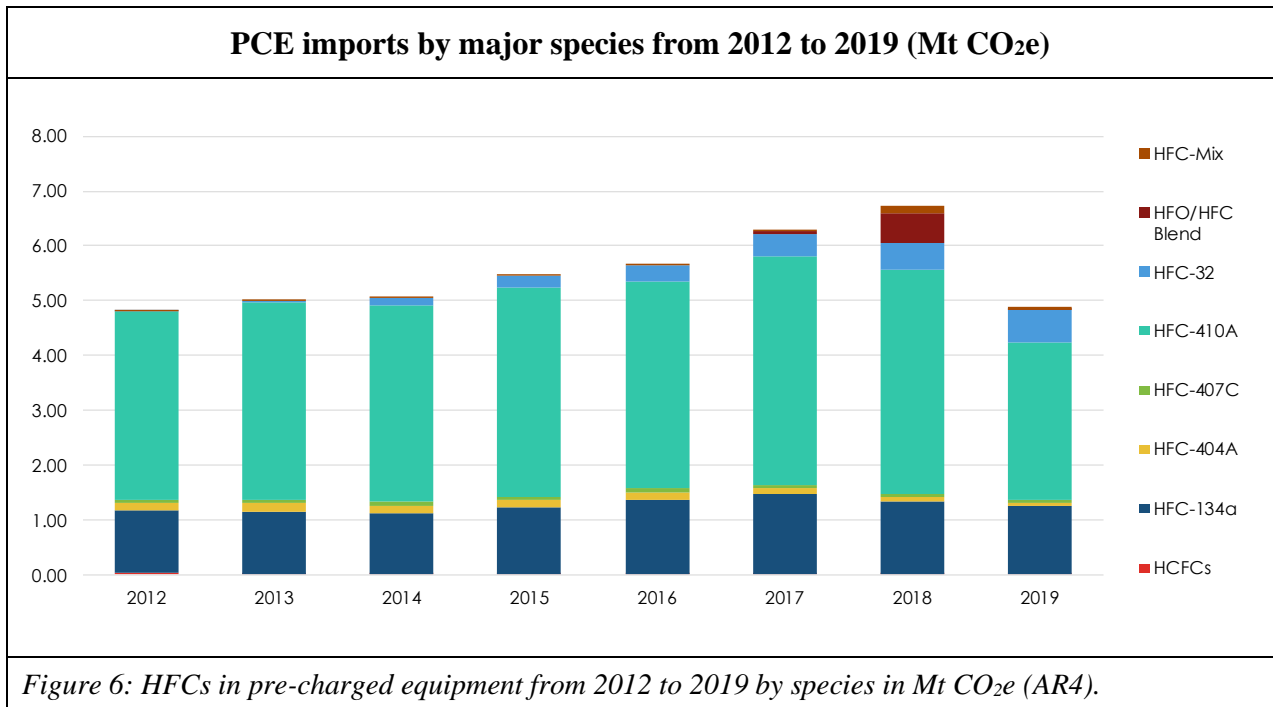


(Sources: DAWE 2020)

1. Refer to *Appendix B Tab 3: Bulk imports and pre-charged equipment imports from 2006 to 2019*, for tabulated data.

A comparison of *Figure 5* above and *Figure 6* below demonstrates the effect of the higher GWP gases in dominating a bank when illustrated by its CO₂e value. While it can be seen from *Figure 5* that HFC-32 has capped the equipment imports of PCE charged with HFC-410A, the higher GWP value of HFC-410A (for some 16 years as the refrigerant of choice in small split AC imports) ensures it will dominate the GWP of the refrigerant bank for many years to come.

¹⁴ R514A is a blend of 74.7% HFO-1336mzz and 25.3% trans-Dichloroethylene.



(Source: DAWE 2020)

6.1.1 Analysis of pre-charged equipment provides insights into the transitioning bank

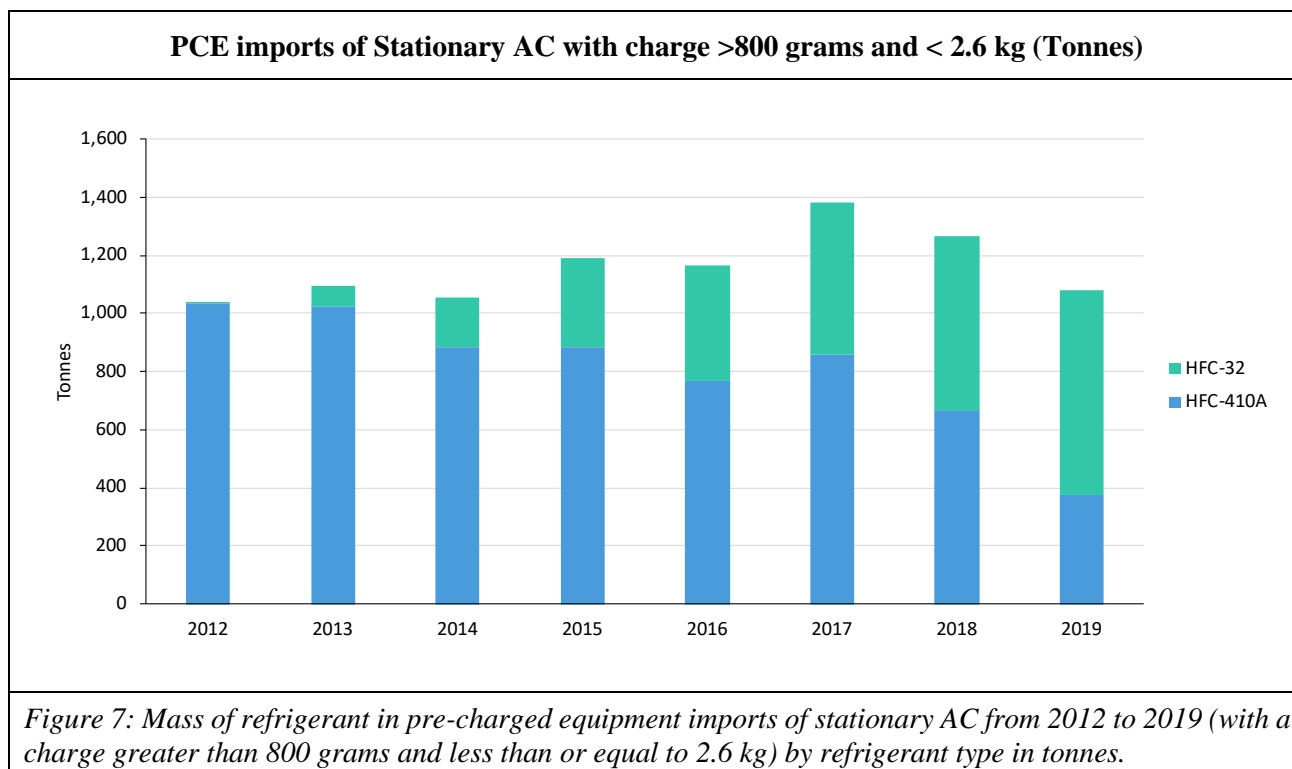
Analysis of PCE imports shows that non-ducted single split systems, designed primarily for residential use, make up the majority of equipment. Non-ducted single split systems contain the bulk of the refrigerant mass¹⁵ of all stationary AC imported into Australia. HFC-32 adoption has continued to grow strongly in non-ducted split systems.

Filtering out equipment with charges less than 800 grams and greater than 2,600 grams excludes the majority of the small portable AC and window wall units that are typically under 800 grams, and the majority of the larger ducted systems, which generally have charges larger than 2,600 grams. These larger units are most likely to be charged with HFC-410A.

Applying these filters highlights the rate of transition away from the much higher GWP HFC-410A, to HFC-32 in this ‘residential’ size range.

Figure 7 illustrates this trend, refer to *Appendix B Tab 4.2: Stationary AC: Pre-charged equipment* for tabulated data.

¹⁵ Based on actual refrigerant charge sizes.



(Source: DAWE 2020)

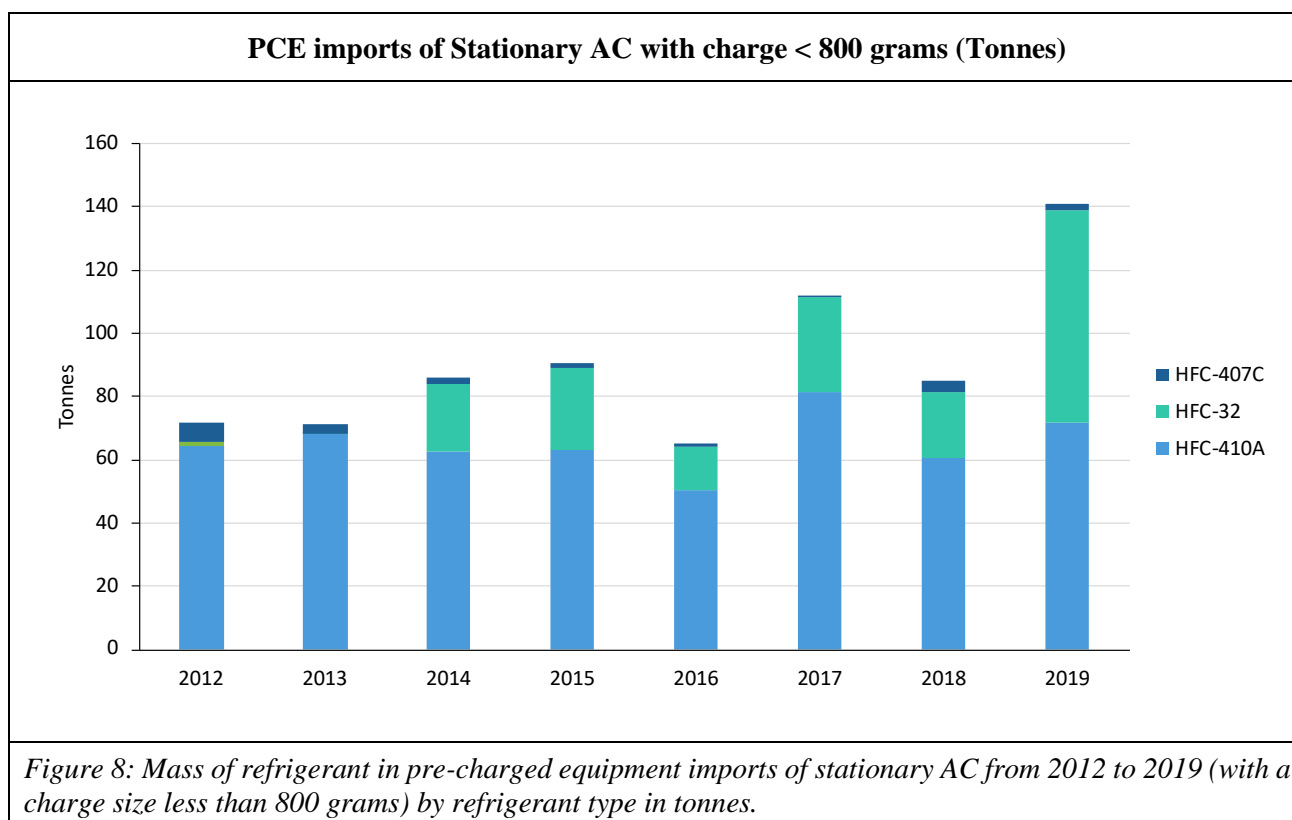
Ducted and non-ducted air conditioners (excluding portable AC) up to 65 kW must satisfy Minimum Energy Performance Standards (MEPS) and be registered under the *Greenhouse and Energy Minimum Standards (GEMS) Act 2012*. The registration details include the refrigerant type.¹⁶ As of the 1st of July 2020, the count of GEMS registered models operating on HFC-32 was:

- 916 non-ducted split systems registered (48% of all registered non-ducted single split systems);
- 110 window/wall models (58% of all registered window/wall); and,
- 182 single split ducted models (21% of all registered single split ducted).

It should be noted however that GEMS data is not sales weighted data, and includes all registered models including those that are no longer on the market. Nonetheless *Figure 8* suggests the current rate of transition of smaller portable devices to HFC-32 is slower than is apparent in the single split systems, and at the same time overall import volumes of portable devices are growing. Recent changes in energy efficiency requirements for some classes of small AC will potentially see a wider range of AC models employing HFC-32.¹⁷

¹⁶ www.energyrating.gov.au

¹⁷ In March 2019 the Federal Energy Minister signed a new Determination for air conditioners under the *Greenhouse and Energy Minimum Standards (GEMS) Act 2012*. Specific changes include applying MEPS to single duct portable air conditioners, increasing MEPS for air conditioners with a capacity greater than 65 kW, reducing MEPS for double duct portable air conditioners, and adopting the Seasonal Energy Efficiency Ratio (SEER) standard for rating air conditioner energy efficiency on the energy rating label.



(Source: DAWE 2020)

6.2 Bulk refrigerant imports

The second source of growth in the bank is via the import of bulk refrigerant. A controlled substances licence (and quota) is required to import bulk HCFCs and HFCs, and holders of these licences are required to report all imports.

Bulk imports of HFCs and HCFCs occur mainly in iso-tanks containing as much as 18 tonnes each. Bulk imports are brought into the country by 35 licensed importers of HFCs and five licensed importers of HCFCs. In 2012 there were only 17 controlled substances licence holders in total.¹⁸

In 2019 a total of 3,534 tonnes of HFCs and 45 tonnes of HCFCs were imported as bulk gas. Total 2019 imports were 102 tonnes (432 kt CO₂e) less than 2018. Refer to *Appendix B Tab 4.1* for tabulated data on HFC and HCFC bulk imports from 2008 to 2019 in tonnes and in kt CO₂e.

¹⁸ List of licences and exemptions granted under the Ozone Protection and Synthetic Greenhouse Gas Management Act 1989, issued February 2012 and March 2020. There are other entities including the Department of Agriculture, Water and the Environment that have an essential use licence and four entities that have a used substance licence.

Table 4: Bulk imports of HCFCs and HFCs in tonnes.

Species	2016	2017	2018	2019
HCFC-22 ⁽¹⁾	45	45	45	45
HFC-134a	1,541	1,837	1,552	1,335
HFC-404A	384	2,008 ⁽⁶⁾	699	838
HFC-407C	190	314	154	179
HFC-407A/F	0	0	0	1
HFC-410A	602	953	999	889
HCFC/CFC Replacements ⁽²⁾	118	110	80	111
HFC-32	27	31	68	64
HFO/HFC Blends ⁽³⁾	0.0	14.6	28.7	27
HFC-Mix ⁽⁴⁾	144	155	79	92
Total HCFCs and HFCs ⁽⁵⁾	3,058	5,734	3,757	3,596 ⁽⁷⁾

Notes:

1. Maximum imports of HCFCs for 2016 to 2019 are capped at 2.5 ODP tonnes per annum, which equates to 45.5 metric tonnes of HCFC-22.
2. HCFC-22/CFC retrofit replacements include HFC-422D, HFC-437A, HFC-417A, HFC-422A, HFC-438A, HFC-426A, HFC-424A, HFC-428A, HCFC-508A, HCFC-508B, HCFC-408A and HCFC-409A.
3. HFO/HFC blends includes R448A, R449A, R450A, R452A, R513A, R515A and others imported from 2017. The values in *Table 4* include the HFC value only (i.e. 27 tonnes in 2019). The combined HFO and HFC value in 2019 is 41 tonnes which is consistent with 38 tonnes of HFO/HFC blends used, cited in *Table 5*.
4. Majority used in foam and fire protection applications as well as HFC-125 that could be used in refrigerant blends.
5. Sum of values in table do not add up to totals due to rounding.
6. The phase down of HFCs through a quota system for imports of HFCs as bulk gas commenced on 1 January 2018.
7. The import values are net values imported that excludes the 5% allowance for the heel and 7.8 tonnes that were exported in 2019.

6.3 Refrigerant usage – HCFCs and HFCs

Insight into refrigerant usage in the Australian economy has significantly improved over the course of the last decade and is now informed by a quarterly survey of refrigerant wholesalers, providing robust data that can be reconciled against annual bulk imports.

Refrigerant is used for several purposes including:

- Local equipment manufacturing, particularly in medium commercial AC, large chillers, hot water heat pumps and refrigerated display cabinets. These are equipment segments where Australia retains successful manufacturers. Refrigerant consumption from local manufacturing of stationary AC in 2019 was 305 tonnes of HFC-410A and HFC-134a.
- Charging, or adding to a partial charge, for new equipment at point of installation where the device may have been imported without any refrigerant charge (or partial charge) or needs an addition to its pre-charged volume when installed and commissioned to accommodate applications with longer pipe runs.
- Retrofitting existing equipment with a new refrigerant, for instance in cases where equipment originally designed and installed to operate on HCFC-22 is able to be retrofitted with drop-in replacements.
- Refrigerants such as HFO/HFC blends R448A and R449A will be considered as retrofit replacements for HFC-404A when the price of HFC-404A increases in time due to its high GWP and the HFC phase down.
- Servicing the stock of equipment to maintain charge levels as a result of leaks or catastrophic losses of refrigerant.
- A small fraction of imports is lost during decanting into small cylinders that are distributed into wholesale supply lines.

Table 5: HCFC and HFC refrigerant usage in tonnes.

Species	2016	2017	2018	2019
HCFC-22 ⁽¹⁾	255	224	168	138
HFC-134a	1,276	1,428	1,329	1,456
HFC-404A	800	878	813	822
HFC-407C	168	173	179	181
HFC-407A/F	33	31	29	28
HFC-410A	612	711	753	799
HCFC/CFC Replacements ⁽²⁾	99	96	44	39
HFC-32	16	32	96	93
HFO/HFC Blends ⁽³⁾	-	-	13	38
HFC-Mix ⁽⁴⁾	190	195	195	201
Total HCFCs and HFCs	3,449	3,768	3,619	3,795

Notes:

1. Maximum imports of HCFCs for 2016 to 2019 are capped at 2.5 ODP tonnes per annum, which equates to 45.5 metric tonnes of HCFC-22. The additional usage in those years of 210, 179, 117 and 93 tonnes of HCFC refrigerants is possible because the material has been reclaimed and reconditioned to AHRI 700 standard so that it can be resold. There would be additional HCFC-22 recovered by contractors and re-used.
2. HCFC-22/CFC retrofit replacements include HFC-422D, HFC-437A, HFC-417A, HFC-422A, HFC-438A, HFC-426A, HFC-424A, HFC-428A, HCFC-508A, HCFC-508B, HCFC-408A and HCFC-409A.
3. HFO/HFC Blends includes R448A, R449A, R450A, R452A, R455A, R513A, R515A and others imported from 2017. The value includes the HFO and HFC component.
4. Majority used in foam and fire protection applications as well as HFC-125 that could be used in refrigerant blends.

6.4 Hydrofluoro-olefin refrigerants (HFOs)

HFOs have very-low GWPs (<10), and in many applications require a smaller refrigerant charge to deliver the same refrigerating effect. Like HCs, the effectiveness of HFOs as a refrigerant mean that in some applications the same refrigerating effect can be achieved while reducing electricity consumed. HFOs were released into international markets from around 2011 and were expected to make relatively rapid in-roads into the bank of refrigerants imported in MAC in new passenger vehicles. International auto makers adopted HFOs for most major markets including the US, EU and Japan from around 2017, in part driven by European F-Gas requirements. At the time of writing HFOs have not been imported in MAC in significant volumes.

The HFO refrigerants with a GWP less than 10 are HFO-1234yf, HFO-1234ze, HFO-1233zd and HFO-1336mzz. The main applications for these refrigerants in Australia in 2018 are supplies to the automotive supply chain and for charging space chillers. Volumes of these refrigerants imported as bulk refrigerants to date are estimated at less than 20 tonnes.

It is expected that trends in global vehicle and equipment manufacturing will see HFO volumes increase markedly through the mid-2020s, delivering a corresponding decrease in volumes of some of the high GWP

HFCs, particularly HFC-134a. As imports of HFO PCE or bulk HFOs are not reportable under current regulatory arrangements, reliable sources of data on import and use of HFOs are still being developed with industry.

6.5 HFO/HFC blend refrigerants

While pure HFOs have not taken as much market share as predicted in the last few years, HFO/HFC blends have begun to be deployed in the market with an estimated 38 tonnes used in 2019. The properties of these blends, and their ability to act as lower GWP, higher efficiency, and in some instances drop-in replacements gives equipment designers and owners options for extending the life of equipment, improving operation and moving to lower GWP refrigerants.

While it is early days in the acceptance of HFO/HFC blends in the market, their adoption in some populous classes of equipment, such as the use of R448A, R449A, R450A, R452A, R455A and possibly others in commercial refrigeration applications, is a trend that will be watched closely in subsequent editions of Cold Hard Facts.

HFO/HFC blends observed in chillers in Australia were R513A and R515A.

Other HFO/HFC blends emerging globally are the A2L classified R452B, R454A, R454B, R454C and R457A that were recently listed by the Significant New Alternatives Policy (SNAP) Program of the United States Environmental Protection Agency for use in air conditioning and heat pump applications. These refrigerant blends are mostly available in US designs and are offered by some European manufacturers, but not Japanese manufacturers. They have not been observed in the Australian market.

6.6 Natural refrigerants

Natural refrigerants are employed to some extent in most RAC technology segments, although with minimal applications in stationary air conditioning.

Commercial and domestic refrigeration has led the way in the adoption of natural refrigerants. The transition of domestic refrigeration equipment to hydrocarbons, a trend that had barely started in 2012, is now effectively complete, with 99% of all domestic refrigeration models examined in a retail survey now found to be charged with hydrocarbons. In more recent years this move to HCs in domestic refrigeration has extended to smaller commercial equipment in Australia with around 5% of the bank of self-contained commercial refrigeration equipment now being hydrocarbon and expected to grow rapidly.

Natural refrigerants are firmly entrenched in the mainstream supermarket sector with larger commercial refrigeration systems. They are increasingly employed in supermarket rack systems and food processing applications, now employing a number of highly efficient options including: CO₂ cascade systems; CO₂ only trans-critical systems; CO₂/ammonia chillers; CO₂/brine; and, other variations of two stage cascade refrigeration systems.

This trend is accelerating in larger supermarkets, largely because of the significant associated energy efficiency gains. Smaller CO₂ condensing unit combinations up to 15 kW which are suitable for small format supermarkets, convenience stores, liquor outlets and fast food chains are also being developed.

The volumes of CO₂ refrigerant used, primarily in the supermarket sector, are increasing from a low base and are now estimated at around 215 tonnes in 2019.

Ammonia is also finding broader application outside the large cold storage distribution centres and industrial chillers where it has been traditionally used. In recent years applications deployed in Australia include ammonia chillers and low charge ammonia chiller packages.

Ammonia volumes are generally driven by large capital works and ongoing maintenance of existing systems with yearly volumes fluctuating accordingly; the six-year average annual use is estimated at almost 700 tonnes.

Table 6: Volumes of ammonia and hydrocarbon sold by calendar year (tonnes) based on supplier survey.

	2014	2015	2016	2017	2018	2019
Ammonia	837	712	577	722	643	684
Hydrocarbon	82	75.0	72	78	88	100 ⁽³⁾

Notes:

1. Volumes exclude non-HVAC&R applications.
2. Survey participants include major participants at the top of the supply chain as well as suppliers further down the supply chain, however these suppliers were not double counted.
3. Includes estimates of some participants and volumes include export.

6.7 Refrigerant usage projection and the HFC phase down

Australia commenced a phase-down of HFC imports on 1 January 2018 implemented as a gradual reduction in the maximum amount of bulk HFCs permitted to be imported into Australia in any calendar year, measured in million tonnes (Mt) CO₂-e per year. The HFC import cap is managed through a quota system on imports of bulk gases by the licensed importers. This is a tried and tested system for management and reporting of substances controlled by the Montreal Protocol, established for the management of CFCs and HCFCs during the 1990s.

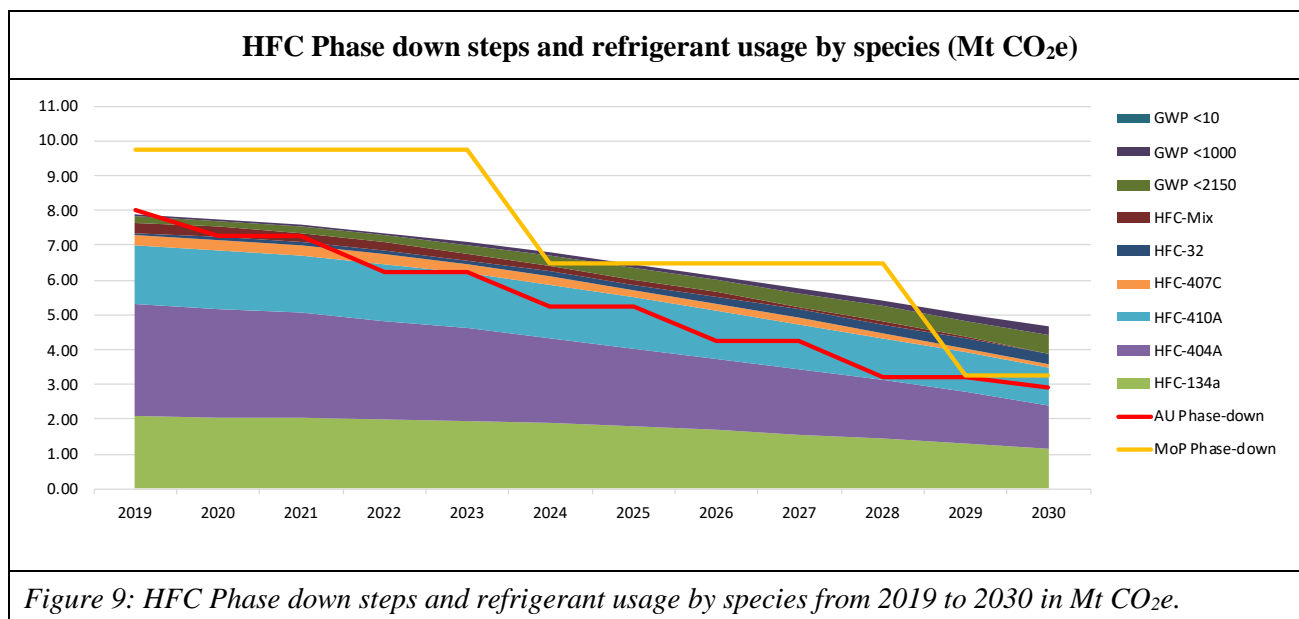
The 2019 annual import limit was 8 million tonnes (Mt) CO₂e. Data reported to the Department of Agriculture, Water and Environment and analysed by the Expert Group indicates that total HFC imports in 2019 were equivalent to around 7.83 Mt CO₂e, slightly down from the 2018 figure of 7.91 Mt CO₂e.

The starting point of the Australian phase-down agreed between the Australian Government and Australian industry participants, is 25% lower than Australia's base level in the Kigali Amendment to the Montreal Protocol. The Australian phase down schedule stipulates reasonably consistent steps down every two years to soften market shocks. The phase down bottoms out in 2036 at the same final point as agreed under the Kigali Amendment to the Montreal Protocol.

The phase down introduces reductions at the start of each two-yearly quota period, aligned with licensing periods under the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*. The phase down has an end point of 1.607 Mt CO₂e on 31 December 2035 and will remain at 1.607 Mt CO₂e for each quota period from then on.

Figure 9 illustrates the HFC phase-down steps to 2030 relative to the projected refrigerant use by species in Mt CO₂e. While there is inherent uncertainty in aspects of the modelling and subsequent projections of demand and use, the Expert Group projections of refrigerant use show demand will at times be slightly higher than imports permitted under the phase down. Some of this demand will be met by recovery and reuse of refrigerants, and by refrigerants already in the country. Some of this demand may also be met by lower GWP, HFO/HFC drop in replacements that are expected to be introduced to market in the period of the projection.

In line with the expected decrease of the CO₂e value of the bank and direct emissions, the CO₂e value of refrigerants used is expected to drop by more than 40% from around 7.44 million tonnes CO₂e in 2019 to around 4.6 million tonnes CO₂e in 2030, five years prior to the final year of the phase down schedule.



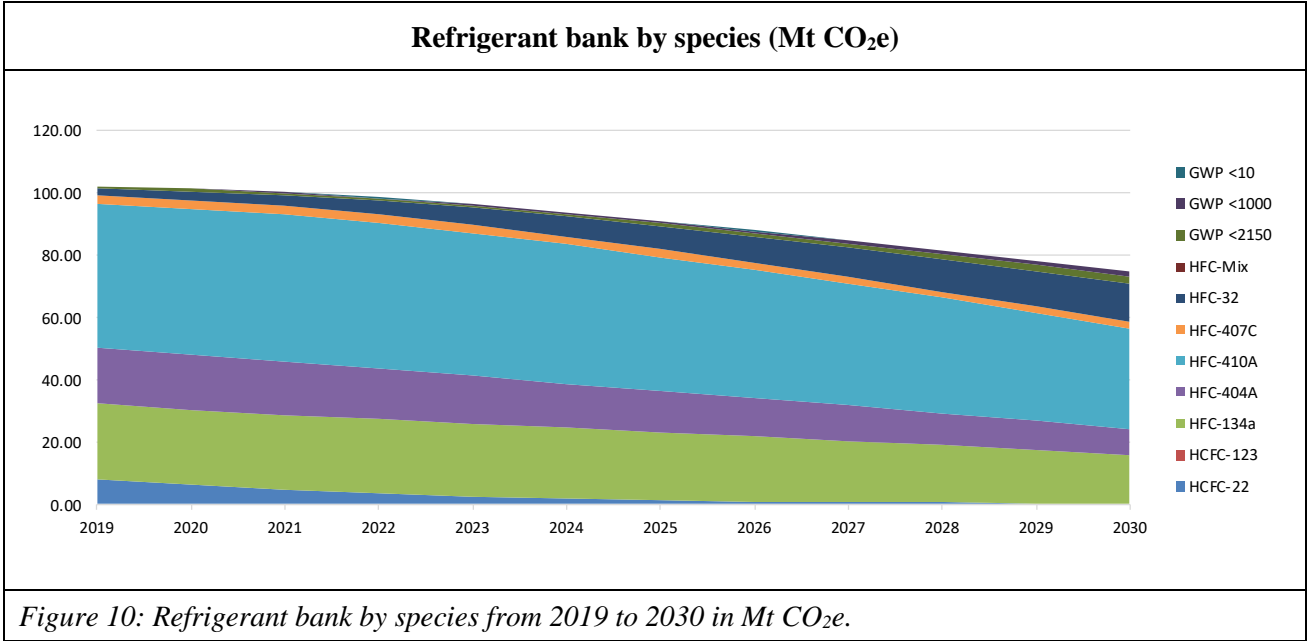
(Source: CHF 2020 RAC Stock Model)

Notes:

1. HCFCs are not included in the above chart as emissions of ODS are not counted as part of the GHGs reported under the Kyoto Protocol of the United Nations Framework Convention on Climate Change, as they managed through the Montreal Protocol.
2. Montreal Protocol HFC baseline for Australia is 10,813,465 t CO₂e, and the control limit for 2019 is 90% of the baseline equating to 9.732 Mt CO₂e.

Just as the CO₂ equivalent value of refrigerant use, and refrigerant imports, declines over the projection period, so too does the total CO₂e of the refrigerant bank. The refrigerant bank is a lagging indicator of changes to the mix of refrigerant species being introduced to service. The composition of the bank also indicates future demand as the stocks of underlying equipment age and lose some part of their charge to leaks which then creates demand for refrigerant use in service.

Figure 10 illustrates the projection of the bank in Mt CO₂e over the same time frame as the phase down steps illustrated in Figure 9. As stated earlier in the report, after decades of growth in CO₂e terms, all data and projections indicate that the peak CO₂e of the overall refrigerant bank has been reached in around 2019. The overall bank comprises various classes and segments, some of which will not reach peak bank for some time (e.g. refrigerated cold food chain).



(Source: CHF 2020 RAC Stock Model)