Heat pumps – Emerging trends in the Australian market

SEPTEMBER 2023

Australian Government
Department of Climate Change, Energy, the Environment and Water

EXPERTGROUP

This publication has been funded by the Department of Climate Change, Energy, the Environment and Water.
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Cataloguing data

This publication (and any material sourced from it) should be attributed as: Heat pumps – Emerging trends in the Australian market, Peter Brodribb, Michael McCann, Jelena Franjic and Graeme Dewerson, report prepared for the Department of Climate Change, Energy, the Environment and Water, Canberra. CC BY 4.0.

This publication is available at www.dcceew.gov.au/environment/protection/ozone/publications.

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Acknowledgement of Country

We acknowledge the Traditional Custodians of Australia and their continuing connection to land and sea, waters, environment and community. We pay our respects to the Traditional Custodians of the lands we live and work on, their culture, and their Elders past and present.

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1 Executive summary

In recent years heat pumps have been recognised as an integral technology in the global effort to improve energy efficiency as part of decarbonisation. Governments of the largest and most advanced economies in Europe, the US, Japan, China and Australia are deploying policies and incentives which are driving dramatic growth in the technological advancement, manufacture, and sales of heat pump technologies across a range of applications. In Australia, Governments are continuing to roll out programs and incentives aimed at accelerating energy efficiency improvements. Consequently, heat pumps are playing an increasingly larger role in these efforts across both commercial and residential sectors in applications including space heating and cooling, hot water heating, clothes dryers and swimming pool heating.

Despite the well documented advantages of the technology and resulting positive contributions towards decarbonisation on a global level, heat pumps deployed around the world in increasing numbers are primarily charged with hydrofluorocarbon (HFC) refrigerants that have high global warming potentials (GWP). These HFCs are subject to an international agreement to significantly phase down production and bulk imports under the Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer. Under the agreement, participating countries, including Australia, are restricted by a diminishing quota system which limits bulk imports of HFCs. Although HFCs used in pre-charged equipment are accounted for in the country of manufacture, ongoing servicing, and end of life management of this growing technology requires consideration. Therefore, this study was designed to assess the demands on future refrigerant usage to 2036 with an expected increase in heat pump deployment.

A summary of key messages from the report are as follows:

- Australia is experiencing a surge of heat pump sales that is expected to continue at least into the mid-2030s as heat pumps continue to replace gas appliances in both existing and new buildings.
- The additional HFC usage from the surge in heat pumps is estimated to add up to 0.071 million tonnes of carbon dioxide equivalent (Mt CO_2e), equating to around 4.4% of the Montreal Protocol limit of 1.622 Mt CO_2e in 2036.
- The largest emission risk from this equipment – hermetically sealed heat pumps and split system air conditioners – will be at end of life. There is no national legislative approach to the end-of-life disposal and recycling of heat pumps, air conditioning equipment and refrigeration equipment.
- To date there have been few restrictions on the GWP of refrigerants in heat pump equipment however this is changing with international and Australian regulations and incentives expected to influence manufacturers' choice of refrigerant in products sold in Australia, particularly:
    - From 1 July 2024 the Australian Government will ban the import and manufacture of small air conditioners using refrigerant with a GWP over 750.
    - The amendments to the European Regulation No 517/2014 (the F-gas regulations).

- The Victorian Energy Upgrades program proposed that hot water heat pumps with refrigerants with a GWP greater than 700 will not be eligible under the Victorian Energy Upgrades program after 1 July 2024 (DEWLP 2022).

2 Introduction

2.1 Description of technology

Heat pumps use vapour compression heat transfer technology similar to that found in a refrigerator. Heat pumps use electricity and refrigerant to extract heat from a source, such as the surrounding air, water or ground and transfer heat from a cool space to a warm space, making the cool space cooler and the warm space warmer. As most of the heat is transferred rather than generated, heat pumps are far more efficient than conventional heating technologies such as boilers, gas heaters or electric resistance heaters, and can be less expensive to run.

The most common type of heat pump is the air-to-air heat pump commonly referred to as a reverse cycle air conditioner or air source heat pump, which transfers heat between the outside air and your house or a building. Air-to-water heat pumps are an emerging application, when connected to a water tank, this type of heat pump can transfer heat from the outside air to a water storage tank which supplies hot water for residential and commercial settings. Examples of equipment that use a refrigeration cycle that are not heat pumps include domestic and commercial refrigerators; mobile air conditioners (except in electric vehicles which may have a heat pump); and commercial chillers, (except for multi-function chillers that have a heating function).

In Australia recent sales data shows that hot water heat pumps are replacing gas and electric resistive hot water services, air-to-air heat pumps are replacing gas ducted heaters and room space heaters, and larger multi-function chillers capable of both heating and cooling have potential to replace gas boilers in commercial applications.

2.2 International overview, the key drivers, and emerging technologies

Global initiatives to reduce greenhouse gas (GHG) emissions, by replacing gas heating and inefficient electrical technologies with heat pumps, are leading to a rapid uptake of a variety of heat pump technologies around the world.

2.2.1 Europe

Heat pumps are widely seen as one of the most important technologies for energy security and decarbonising heating in Europe. Since Russia's invasion of Ukraine, the resulting energy crisis and related policy intervention, many European states are continuing to prioritise a rapid transition from fossil fuels to renewable energy and electrification (Rosenow and Gibb 2023). In small and medium scale heating applications that shift is driving demand for heat pumps.

A record 3 million heat pumps were sold across Europe in 2022, a 34% increase on 2021 and a significant increase on the previous average annual growth of approximately 10% per annum throughout most of the last decade (Rosenow and Gibb 2023).

The European Commission has recently opened its call for evidence on its proposed heat pump action plan to accelerate deployment of the technology in the European Union (EU) with the objective of installing at least 10 million additional heat pumps by 2027 (Cooling Post 2023d) in line with its REPowerEU plan.

The European Commission put forward the REPowerEU plan in May 2022. The plan builds on the implementation of the 'Fit for 55' proposals, which support the ambitious EU goal of achieving a reduction of at least 55% net greenhouse gas emissions by 2030 and climate neutrality by 2050, in line with the European Green Deal. Among the measures supported by the plan are decarbonising industry, accelerating the deployment of renewables and boosting energy efficiency through the uptake of heat pumps (Council of the EU 2023b).

Simultaneous to, and at odds with these plans for accelerated heat pump roll out, in a recent vote on amendments to the European Regulation No 517/2014 (the F-gas regulations) revision proposals, the European Parliament's environment committee voted to fast-track the phase down of hydrofluorocarbon (HFC) refrigerants in a number of applications, including heat pumps.

The revised F-gas regulations, if implemented, would mean a ban on use of HFCs from as early as 2026 for some heat pump types. The vote presents a challenge to EU's decarbonisation and energy security ambitions, as well as the REPowerEU plan, as HFC refrigerants are instrumental to the functioning of heat pumps and the proposed regulations would affect almost 30 thousand different models of equipment currently present in the European market (APPLia 2023). At the time of writing, negotiations are ongoing between the EU Council and EU Commission, however following industry consultation the revised F-Gas Regulation includes some easing of bans that seem more achievable for industry. In addition, a transition from HFCs to low global warming potential (GWP) alternatives, such as hydrocarbons (HC-290) and HFOs, involves consideration of training of installers, safety, energy efficiency and product affordability (Cooling Post 2023a, Cooling Post 2023b, Cooling Post 2023c).

Monobloc technology is one of the more significant air-to-water heat pump technologies that is making inroads into the colder UK and European markets. Monobloc refers to a 'single block' system, where all of the components, apart from the hot water cylinder, are fitted into a heat pump unit placed outside the building (HVP 2020). These self-contained systems do not require refrigerant piping and can be easily mounted to the exterior of a building with the hot water storage cylinder located inside the building and connected by only the water piping (Electronics 2022).

The monobloc design offers significant opportunities for refrigerants with GWP of less than 150, such as pure propane, HC-290 (GWP of 3), and HFC/HFO blend R454C (GWP of 148). Although this is a good technology option for Europe and colder climates that predominantly require heating, it doesn't necessarily provide a great opportunity for warmer climates such as Australia where cooling is the dominant comfort requirement, and hydronic heating systems represent a very small portion of the market.

From 2019 to 2023, the EU funded the TRI-HP project (tri-generation systems – heating, cooling and electricity - based on heat pumps with natural refrigerants and multiple renewable energy sources) aimed at offering tailored solutions for European multi-family buildings using trigeneration technology. This program has a goal of reducing costs by up to 15% in comparison with the existing hydronic heat pump technologies and decreasing greenhouse gas emissions from gas boilers and air chillers by 75%. Tri-generation systems are typically based on natural refrigerant heat pumps coupled with renewable electricity generators (e.g., solar photovoltaic), using cold storage (such as an ice slurry), heat and electricity storages to provide heating, cooling and electricity. They typically utilise three energy sources, solar, ground source and ambient air, and include advanced controls, managing electricity, heat and cooling in a way that optimises the performance of the system (European Commission 2019).

Although a number of unique solutions for various applications have been developed in Europe, tri-generation systems are most suitable for bespoke projects using hydronic heating, with limited application potential in Australia. This EU effort is already generating novel solutions and driving innovation in development and demonstration of tri-generation applications. A watching brief should be maintained looking for technologies suited to Australian applications in commercial, industrial, health and hotel sectors.

2.2.2 United States of America

The United States of America (US) is also taking proactive measures to encourage a faster shift to heat pump technology. In 2021 the US Department of Energy launched the residential Cold Climate Heat Pump Technology Challenge to accelerate the deployment of cold climate heat pump technologies (U.S. Department of Energy 2021). Manufacturers including Rheem, Carrier, Daikin, Johnson Controls, Lennox and Mitsubishi Electric accepted the challenge aimed at reducing the carbon footprint of cold climate heating solutions by improving efficiency and affordability (Cooling Post 2023f).

The United States Department of Defense recently announced $250 million, funded through the Inflation Reduction Act, to increase domestic production of heat pumps using the Defense Production Act (DPA) authorities invoked by President Biden in 2022. The DPA determinations are part of the US plan to lower energy costs, strengthen national security, and achieve energy independence by reducing demand for natural resources (U.S. Department of Energy 2023).

The 2022 Inflation Reduction Act is the largest step that congress has taken to address climate change. It aims to reduce Americans' energy costs, create good jobs and transform US efforts to address the climate crisis. Not only does the Inflation Reduction Act incentivise industry, but it also provides direct incentives for American families to decarbonise their homes through the conversion to cleaner energy, including heat pumps (Barbanell 2022). Of the US$394 billion committed, the Inflation Reduction Act provides nearly US$9 billion for home energy rebate programs to electrify appliances, introduce solar and battery storage and retrofit properties to make them more energy efficient. Qualifying home improvements are eligible for a tax credit of up to 30% of the total cost, capped at US$1,200 annually. For heat pumps, the credit is capped at US$2,000 per year (AEC 2023). Heat pump technologies listed as eligible for rebates under the Home Electrification Project Qualified Technologies include energy star water heaters (up to USD$1,750), space heating and cooling (up to USD$8,000) and clothes dryers (up to USD$840) (U.S. Department of Energy n.d.).

2.2.3 China

China has been working to reduce its reliance on coal for domestic heating to improve indoor and outdoor air quality, while moving towards heat pumps as part of decarbonisation plans (China Daily 2022). In 2013 the Chinese government introduced the 'Air Pollution Prevention and Control Action Plan' which accelerated the use of centralised and district heating encouraging a switch to cleaner fuels. This policy was followed by the 2017 'Clean Winter Heating Plan' for Northern China aimed at improving urban air quality and reducing overall energy consumption, as well as reducing water and heat loss (University of Birmingham 2023).

Despite a slowdown in sales growth there were more heat pumps sold in China than any other country in 2022. China also has the largest workforce in the sector globally and operates a 40% share of the world's heat pump manufacturing capacity, making it the world's largest producer and exporter of heat pump technology, with most exports going to Europe. In Northern China, district heating dominates as the most common heating solution in cities although many households have heat pumps installed for space cooling and periodic heating. In Southern China, where the climate is warmer during winter, air source reversible units are a widespread solution for space heating. More than 1 million air sourced heat pumps were sold throughout China in 2022 (IEA 2022, Monschauer et al. 2023).

2.3 Trends and observations by refrigerant type

Table 1 illustrates the state of technology readiness (green, amber and red) for the main heat pump equipment classes to transition to lower GWP HFCs or alternative refrigerants. This framework, combined with interviews with technical experts from global equipment suppliers, forms the basis for predicting new equipment sales mix projections to 2036, which in turn inform the projections of the future composition of the refrigerant bank. The sections that follow provide some examples to support the technology readiness assessment and alternative refrigerant selections.

Further technical information including the taxonomy of technology, and technical characteristics (i.e., average charges, service rates and nominal lifespans) by product category is provided in Appendix A.

Table 1: Summary of technology opportunities for new heat pump equipment by GWP threshold

New equipment	Equipment examples	New equipment technical capability (GWP threshold)			
		10	150	500	700
Heat pump clothes dryers	Heat pump clothes dryers	HC-290 **a**	N/A	N/A	R450A **a** R513A **b**
Domestic hot water heat pumps	Hot water heat pump: domestic, incl. residential and commercial as well as cascade systems	HC-290 **a** CO_2 **a**	R454C **b**	N/A	HFC-32 **a** R513A **b**
Swimming pool heat pumps	Pool heat pumps	HC-290 **b**	N/A	N/A	HFC-32 **a**
Small air conditioner: Room air conditioner	Single split system: non-ducted (wall hung, cassette, console and under ceiling units)	HC-290 **b**	R454C **c** R455A **c**	N/A	HFC-32 **a**
Medium air conditioner: Multi room	Single split system: ducted, roof top packaged systems, VRV/VRF split systems	N/A	R454C **c** R455A **c**	R454B **b** R468C **b**	HFC-32 **a**
Commercial heat pumps	Commercial heat pump and multi-function chillers (air source hot water heat pumps with water temperatures ≤ 85 degrees), Other (i.e., water source and ground source hot water heat pumps, and industrial applications with water temperatures > 85 degrees)	CO_2 **a** HC-290 **a** Ammonia **a** HFO-1234ze **a**	R454C **a**	R454B **a**	HFC-32 **a** R513A **a**

Key to technology signals

Mature technology within the Australian market.

Technology available but not widely utilised within the Australian market.

Technology not available at this time, there may be pilot trials underway.

CO_2 carbon dioxide **GWP** global warming potential **HC** hydrocarbon **HFC** hydrofluorocarbon **HFO** hydrofluoro-olefin **N/A** not applicable

a Mature technology within the Australian market. **b** Technology available but not widely used within the Australian market. **c** Technology not available at this time, there may be pilot trials underway. **d** Refrigerant selections are based on equipment designs and installations that satisfy the relevant Australian Standards. **e** ASHRAE assigns numbers and safety classification to the refrigerants based on toxicity and flammability. The assigned ASHRAE numbers are used in the above table for HFO/HFC blends (R454B, R454C, R513A, R468C).

2.4 Overview of government initiatives driving heat pump installations

In recent years Australian Federal and State governments have introduced a range of programs and incentives to reduce reliance on gas, increase energy efficiency of equipment and support low-income households that drive the uptake of heat pumps in residential and commercial applications.

Examples of current programs include:

- Financial incentives in the form of Small Technology Certificates administered by the Federal Government's Clean Energy Regulator (CER) for individuals and small businesses to install eligible small-scale renewable energy systems including solar panel systems, small-scale wind systems, small-scale hydro systems, solar water heaters and air source heat pumps for water heating.
- General energy efficiency grants, such as the Federal Energy Efficiency Grants for Small and Medium Sized Enterprises with a pool of $63 million offering grants from $10,000 to $25,000 to cover up to 100% of eligible project expenditure. Round 1 was for a total of $16 million which closed on 29 March 2023 (Commonwealth of Australia 2023).
- The Federal Government's Small Business Energy Incentive provides $314 million in tax relief for energy performance upgrades, including for heat pump technologies (Chalmers 2023).
- The Federal Government's $100 million Community Energy Upgrades Fund will co-fund upgrades with local councils which could include replacing energy-intensive heating in council pools with heat pumps (Albanese et al. 2023).
- Grants and incentives to assist large energy users improve energy efficiency, and support for large scale projects such as the Australian Renewable Energy Agency (ARENA) Industrial Energy Transformation Studies (IETS) Program, and the Federal Emission Reduction Fund administered by the Clean Energy Regulator.
- National Australian Built Environment Rating System (NABERS) and Green Star that is evolving toward a focus on 'embodied carbon' which factors in the carbon emissions from the manufacture of the materials within a building, and which takes refrigerant choice in heating and cooling systems into account.
- Financing for energy efficiency projects from various agencies such as those available from the Federal Clean Energy Finance Corporation and the ACT Sustainable Household Scheme.
- Major incentive schemes including the Victorian Energy Upgrades program and the New South Wales Energy Security Safeguard scheme. The New South Wales scheme encompasses both the NSW Energy Savings Scheme and NSW Peak Demand Reduction Scheme, both of which include methods that specifically target support for heat pump applications.
- Various energy reduction business coaching and mentoring programs (e.g., ACT Government Climate choices; ecoBiz Queensland).

Development and appraisal of the effect of these programs is ongoing by the various agencies involved. It is expected that program outcomes will be reviewed, and results shared with stakeholders to inform design and implementation of future programs targeting gas consumers, improvements in energy efficiency, and support for low-income households.

In 2020 the Victorian Government launched the Home Heating and Cooling Upgrades program. This program was specifically designed to provide energy-efficient heating and cooling for low income and vulnerable households by reducing upfront cost of purchasing energy efficient reverse cycle split systems (DEECA 2023a). In part due to this program, Victoria is now the second largest market for wall hung split systems, overtaking NSW in 2022. This program was wound up on April 30, 2023.

These measures and market interventions will hasten the transition from gas appliances to heat pumps in water heating and space heating/cooling applications in both residential and commercial applications, accelerating a market trend that has strong fundamental underpinnings due to the convenience and relatively high energy efficiency of the better-quality heat pumps. The main schemes that are providing tangible incentives that specifically target heat pump activities are summarised in Table 2.

Table 2: Energy efficiency and renewable energy schemes that are providing tangible incentives that are driving heat pump activities.

Scheme	Method for upgrade activity	Activity	Certificate type (1 MWh)	End user type	Equipment Type
Victorian Energy Upgrades	1D	Water heating	Victorian Energy Efficiency Certificate **(a)**	Residential	Replace electric resistive with hot water heat pump.
	3C				Replace gas with hot water heat pump.
	44A-C			Business	Replacing commercial or industrial electric resistive, gas or new installation with hot water heat pump.
	6	Space heating and cooling		Residential	Decommission/removal of gas space heating appliance, and install an air conditioner (i.e., single, multi split and ducted systems).
	Project Based Activities (PBA)			Business	Project based activities provide incentives for large and custom energy saving projects based on measurement and verification method which permits a wide range of technologies including heat pumps.
NSW Energy Security Safeguard	HEER (D17, D19)	Water heating	Energy Saving Certificates **(a)** and Peak Reduction Certificates **(b)**	Residential	Replace an existing electric or gas water heater with an air source heat pump water heater.
	IHEAB (F16, F17), RDUE (WH1)			Business	Replace existing equipment or new installation with air source heat pump water heater systems.
	HEER (D16, D19), RDUE (HVAC1)	Space heating and cooling		Residential	Install a new high efficiency air conditioner or replace an existing air conditioner with a high efficiency air conditioner.
	IHEAB (F4), RDUE (HVAC2)			Business	Install a high efficiency air conditioner or replace an existing air conditioner with a high efficiency air conditioner.
	Project Impact Assessment with Measurement and Verification			Business	Project based activates provide incentives for large and custom energy saving projects based on measurement and verification method which permits a wide range of technologies including heat pumps.
Retailer Energy Productivity Scheme	WH1	Water heating	Activities based on retailer market allocation	Residential and small energy consuming businesses **(d)**	Replace or upgrade water heater.
	HC2A	Space heating and cooling			Install an efficient new reverse cycle air conditioner (non-ducted).
	HC2B				Install an efficient new reverse cycle air conditioner (ducted or multi-split).
Renewable Energy Target	Small-scale Renewable Energy Scheme (SRES)	Water heating	Small-scale technology certificates **(c)**	Residential and business	Air source hot water heat pump with capacity up to and including 425 litres.

IHEAB NSW Installation of High Efficiency Appliances for Businesses **HEER** NSW Home Energy Efficiency Retrofits **RDUE** NSW Reducing Demand Using Energy

(a) Each Victorian Energy Efficiency Certificate (VEEC) or Energy Saving Certificate (ESC) represents one tonne of greenhouse gas emissions reduction (CO_2e). **(b)** Each Peak Reduction Certificate (PRC) represent 0.1 kilowatt of peak demand reduction capacity averaged over one hour during the peak summer period. **(c)** Each small-scale technology certificate (STC) is equal to 1 megawatt hour of renewable electricity either generated or displaced by eligible small-scale renewable energy systems. **(d)** A small energy consuming customer is a non-residential customer consuming less than 160 MWh of electricity in the 12 months prior to any REPS activities being undertaken.

2.4.1 Victoria

In July 2022 the Victorian Government which has a net-zero emissions target of 2050, released a Gas Substitution Roadmap that proposes a number of measures intended to reduce natural gas use (DEECA 2023b). The Roadmap includes energy efficiency initiatives, electrification options, and foreshadows the use of hydrogen and biogas. The ongoing Victoria Energy Upgrades program is an integral part of the Roadmap and is intended to drive growth in heat pump installations.

The Victorian Energy Upgrades program offers incentives to install heat pumps for water heating, and for space heating and cooling for both residential and commercial customers. In 2022 the scheme delivered more than $50 million worth of rebates for heat pump installations in residential and commercial combined. The vast majority of rebates were for residential applications replacing electric resistive water heating. Assuming an average Victorian Energy Efficiency Certificate (VEEC) price of $65, this suggests as much as $49 million in rebates was delivered to households for residential water heating heat pump installations alone in 2022.

The Victorian Energy Upgrades program introduced an expanded activity, Method 6, see Table 2, that commenced on 30 May 2023, offering financial incentives for installing heat pumps that replace gas for space heating with single split, multi-split or ducted systems. Of course, the heat pumps also provide cooling services, which the gas systems being replaced could not, unless they are ducted with add-on refrigerative cooling.

Notably suppliers and contractors who supply and install gas ducted heaters have already reported significant reductions in sales, of between 30% to 50%, of gas fuelled appliances in Victoria in 2022 compared to historical sales volume, particularly into new homes. The introduction of the new Method 6 upgrade activity is expected to also impact gas appliance sales in the replacement market.

In July 2023, the Victorian Government announced that from 1 January 2024, planning permits for new homes and residential subdivisions, including new public and social housing delivered by Homes Victoria will only connect to all electric networks.

2.4.2 New South Wales

The NSW Government's Climate and Energy Action Plan is the foundation for NSW's action on climate change. Stage 1 of the Net Zero Plan is to achieve a 50% reduction in emissions on 2005 levels by 2030, and to reach net zero emissions by 2050 (NSW Treasury 2020).

The plan supports a range of initiatives targeting energy efficiency, electric vehicles, hydrogen production and substitution, primary industries, innovation in the built environment, carbon financing and management of organic waste.

The plan includes the NSW Energy Security Safeguard scheme to support the uptake of energy saving equipment and activities that reduce energy demand of businesses and households. This includes incentives for demand shifting, peak demand reduction technologies, and an expanded energy efficiency program that includes activities that drive installation of various configurations of heat pumps.

In NSW, the Energy Saving Scheme introduced an incentives program in February 2022 for installation of hot water heat pumps for residential and commercial applications, as well as incentives for high efficiency reverse cycle air conditioners. In 2022 the scheme delivered approximately $9.6 million of rebates for heat pumps, assuming an average NSW Energy Saving Certificate (ESC) price of $32 each and Peak Reduction Certificate (PRC) price of $2.00 each. $8.5 million was from residential water heating activities, and the balance in residential space heating and cooling. The number of certificates generated are expected to be much higher in 2023 and include some business activities (IPART 2023).

2.4.3 Australian Capital Territory

As part of its commitment to phase out the use of natural gas, the ACT Government has banned new building gas connections from 2023 (Rae 2023), and has a range of energy efficiency initiatives that include purchase and installation of heat pumps.

Under the Energy Efficiency Improvement Scheme, electricity retailers are required to help households and small to medium businesses save energy by delivering eligible energy savings activities, which include electric space heating and cooling systems and electric hot water heat pumps, or alternatively paying an Energy Savings Contribution (ESC) to the ACT Government. ESCs are used to fund ACT Government-led energy efficiency programs (ACT Government 2023b).

The ACT Government has committed $150 million over five years to provide zero-interest loans under the Sustainable Household Scheme. The scheme enables eligible households and individuals to access zero-interest loans between $2,000 and $15,000 to make energy efficiency upgrades to their homes and premises by purchasing a range of sustainable products including electric space heating and cooling systems and electric hot water heat pumps (ACT Government 2023d).

For eligible homeowners who hold an Australian Government Pensioner Concession Card or Department of Veterans' Affairs Gold Card, the Home Energy Support Program provides up to 50% or $5,000 in rebates to help with the upfront costs of installing these energy-efficient products. Eligible participants have the option of applying for the Sustainable Household Scheme zero-interest loan to finance the balance of the installation costs (ACT Government 2023c).

Similarly, the Business Energy and Water Program provides small to medium businesses with rebates up to $5,000 to upgrade to water-efficient and energy-efficient technologies including heating and cooling, and hot water (ACT Government 2023a).

2.4.4 South Australia

South Australia operates the Retailer Energy Productivity Scheme (REPS) with the objective of improving energy productivity for households, businesses and the broader energy system, with a focus on low-income households (ESCOSA 2023b).

The program includes activities to install heat pumps for hot water, and for space heating and cooling systems for residential and small business customers consuming less than 160 MWh of electricity in the 12 months prior to any REPS activities being undertaken (ESCOSA 2023a).

The South Australian Retailer Energy Productivity scheme operates differently to the Victorian Energy Upgrades program and the NSW Energy Security Safeguard scheme, both of which have dedicated methodologies for heat pump activities. The Retailer Energy Productivity scheme sets annual targets for obliged energy retailers that have significant discretion as to how they achieve those targets. While the Retailer Energy Productivity scheme is a capped market based on the Retailer Energy Productivity scheme targets, it achieved a similar number of installations per 1,000 households in South Australia compared to NSW in 2022. Another unique feature of the Retailer Energy Productivity scheme is it has more compliance obligations on the obliged retailers than those in Victoria and NSW.

2.4.5 National

At a Federal level, the Clean Energy Regulator continues to offer small-scale system renewable energy certificates under the Renewable Energy Target scheme for hot water heat pumps with capacities of no more than 425 litres. This initiative will continue until 2030 when the number of small-scale technology certificates offered for each installation declines. In 2022 the program provided rebates for almost 82,600 hot water heat pumps installations. In some installations customers receive rebates from Renewable Energy Target scheme and the state-based programs. Table 3 provides a summary of the installations that received small-scale technology certificates in 2022. Although this data will not have captured all installations in 2022, it does illustrate the impact of Victorian incentives compared to other states.

Table 3: Installations of hot water heat pumps that received small-scale technology certificates under the Renewable Energy Target scheme in 2022

State	HWHP Installation by State	% by State	Total residential dwellings by state (a)	HWHP Installations per 1,000 dwellings
NSW	14,236	17%	3,364,802	4.2
VIC	47,288	57%	2,810,815	16.8
QLD	8,258	10%	2,195,595	3.8
SA	3,751	5%	808,379	4.6
WA	5,017	6%	1,150,416	4.4
TAS	2,021	2%	259,318	7.8
NT	154	0%	96,564	1.6
ACT	1,870	2%	187,153	10
Totals	82,595	100%	10,873,042	

Source: (ABS 2022)
(a) The reference period for the housing stock is 2021 and includes private occupied and unoccupied dwellings. An estimated 70% of installations claimed STCs in 2022.

The Clean Energy Regulator also administers the creation and issuing of Australian Carbon Credit Units (ACCUs) under the Emissions Reduction Fund (ERF) which includes methods to install high efficiency commercial appliances. However, the design of the relevant methods originally introduced in 2015, and the onerous requirements for participation in the ERF under these methods as compared to the relative simplicity of the Victorian Energy Upgrades program and NSW Energy Security Safeguard scheme, have not driven any significant market change with heat pumps. Methods such as the High Efficiency Commercial Appliances Method, or the Commercial Buildings Method, were intended to incentivise uptake of a wide range of highly efficient technology but are regarded by accredited participants in state-based programs as largely unworkable and too cumbersome to be employed. A new method was introduced in January 2023, the Industrial and Commercial Emissions Reduction method that includes replacing or modifying boilers, or heating, ventilation, and air conditioning systems. The effectiveness of this new method in driving market behaviour change is yet to be seen.

3 Overview of heat pump technologies

3.1 Heat pump clothes dryers

3.1.1 The technology

There are three predominant types of clothes dryer technologies. The most common being the older style, relatively inefficient electric resistive clothes dryer referred to as a vented dryer. Two other types of clothes dryers are the condenser dryer, which is less common, although equally as inefficient, and the newer technology, high efficiency heat pump dryer.

Vented dryers and condenser dryers both use electric resistive heating technology, with a condenser dryer collecting moisture from the wet clothes in a container (sometimes referred to as a reservoir), located within the dryer cabinet itself, while a vented dryer removes the moisture along with air into the surrounding room or through a duct to the outside.

Heat pump clothes dryers (HPCD), which use as little as 40% to 50% of the energy of a conventional electric resistive clothes dryer, contain an evaporator to condense the water vapour from the circulating wet air stream and the dehumidified air is reheated by a condenser, before the hot and dry air returns to the tumble, in a closed air loop. The refrigeration circuit in HPCDs differs from other refrigeration appliances by its very high evaporation temperature (typical 10°C to 30°C) and high condensation temperature (up to 70°C). Most systems use rotary compressors (UNEP 2023).

To be marketed in Australia, clothes dryers must comply with Minimum Energy Performance Standards (MEPS). They are also required to carry a highly visible, and uniformly formatted Energy Rating Label to provide consumers with information about the appliance’s comparative efficiency and estimated annual energy consumption.

Common vented heat pumps are typically available in capacities starting from as low as 4 kg, up to 7 kg, while condenser dryer capacities are commonly 7 kg to 8 kg. The low energy efficiency of both technologies is reflected in an average 2-star rating. HPCDs offer the highest star ratings of any clothes dryer technology ranging from 7-star to 10-star, incorporate a multitude of features and have larger load capacities ranging from 7 kg for a smaller unit, up to 10 kg for a larger one.

3.1.2 The market and sales projection

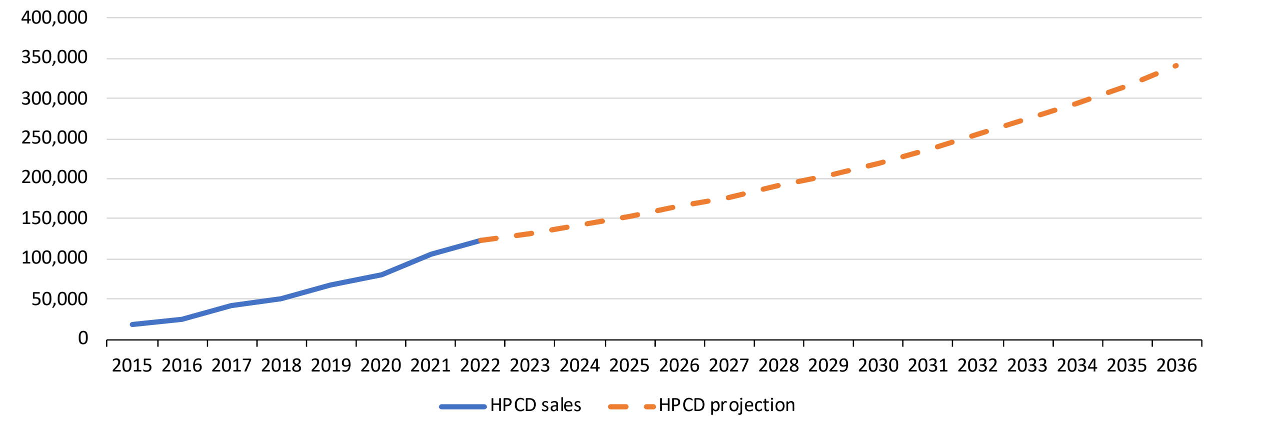
The Australian domestic clothes dryer market is estimated to have averaged sales of 443,000 pieces per annum over the last five years. Recent sales history peaked at 555,000 pieces in 2020, driven in part by the Australian Government’s financial stimulus programs in the face of the COVID-19 pandemic, with a low of around 390,000 pieces sold in 2019 (DISER 2021).

The residential clothes dryer market has changed significantly over the last several years with HPCD models now making up the majority of the models available, resulting in as much as 30% of sales in 2022. All HPCDs are imported by major consumer appliance brands with product manufactured in large scale facilities overseas. Some manufacturers have ceased production of conventional electric resistive dryers.

Over the last seven years, imports of HPCDs have grown strongly by over 400% from 20,000 units and 8 importers in 2015, to over 120,000 units with 12 major importers in 2022.

The simple sales projection below considers historical sales growth of HPCDs, as well as the current penetration and possible future penetration of HPCDs. The assessment assumes sales will continue to grow rapidly with an average compound annual growth rate of 7.5% from 2022 to 2036. The model assumes sales of HPCDs will reach at least 340,000 units in 2036 which equates to a penetration of almost 60% of the projected market size.

Figure 1: Sales and projections for domestic heat pump clothes dryers from 2015 to 2036



Source: (DCCEEW 2023c)

HPCD Heat pump clothes dryer

Data in Figure 1 is based on the following assumptions: All HPCDs are imported and reported as pre-charged equipment (PCE). PCE data includes some washer/HP dryers and clothes drying cabinets. Clothes dryer market is expected to grow at around 1.8%, similar to the historical growth of private dwellings over the last five years (ABS 2022). Assumed 7.5% compound growth from 2022 to 2036.

3.1.3 Other heat pump clothes dryers

Heat pump clothes drying cabinets, sometimes referred to as stylers, have recently emerged on the Australian market giving consumers the option to dry and treat clothing upright on hangers while also offering an array of functions not available with traditional drum dryers, including gentle drying of delicate fabrics, pressing, wrinkle removal, sanitising, and humidity control.

There are currently only three importers of these appliances identified, collectively importing less than 2,000 units per annum with charge sizes ranging from 125 grams to 300 grams of HFC-134a or HFC-407C. Heat pump drying cabinets do not currently feature energy rating labels so efficiency information is not easily accessible for consumers.

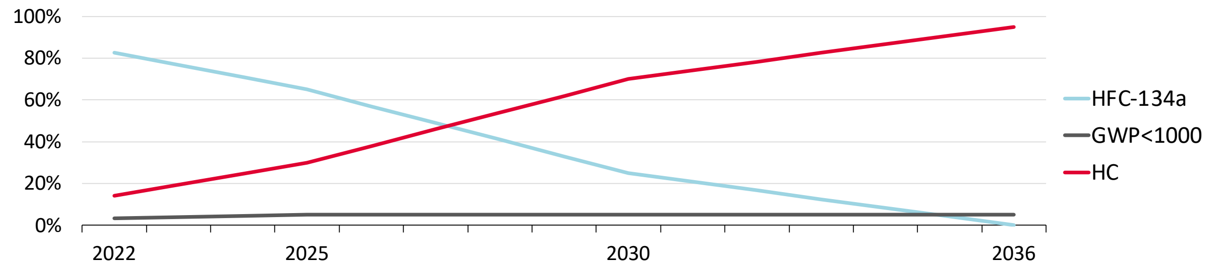
There are also washer and dryer combos that offer an all-in-one washing machine and clothes dryer for smaller households with insufficient space to accommodate two appliances. These washer and dryer combos come in vented, condenser and heat pump versions.

3.1.4 New sales mix projection

The Australian pre-charged equipment (PCE) import data from 2012 to 2022 was analysed to assess the historical charge species and size of charges in imported heat pumps. The dominant refrigerant from 2012 to 2020 was HFC-134a, accounting for more than 95% of units, and the average charge over that period was 420 grams.

Figure 2 provides the new sales mix input projection which forecasts that propane (HC-290) will be the dominant refrigerant accounting for around 90% of installations by 2036. Several brands have already transitioned to HC-290 with high-capacity models achieving high star ratings (i.e., Bosch and Beko, and Miele has commenced transition).

Figure 2: New sales mix projection by units for domestic heat pump clothes dryers from 2022 to 2036



Source: (DCCEEW 2023b)

GWP global warming potential **HFC** hydrofluorocarbon **HC** hydrocarbon

Assumptions: EU F-Gas Regulations is expected to drive technology transition to HC-290. Domestic refrigerators took around 7 years to transition from HFC-134a to HC-290, plausible HPCD will transition in similar time frame. The HC-290 charge size for large capacity (i.e., 9 kg to 10 kg) is below 150 grams so flammability should not be a regulatory barrier in major global markets or Australia. Projections of new sales mix inputs are in units installed and are based on linear projections by species in periods from 2022 to 2025, 2025 to 2030 and 2030 to 2036. These sales mixes are multiplied by respective charge sizes by year to provide new sales mix outputs by refrigerant mass.

3.1.5 Bank projection

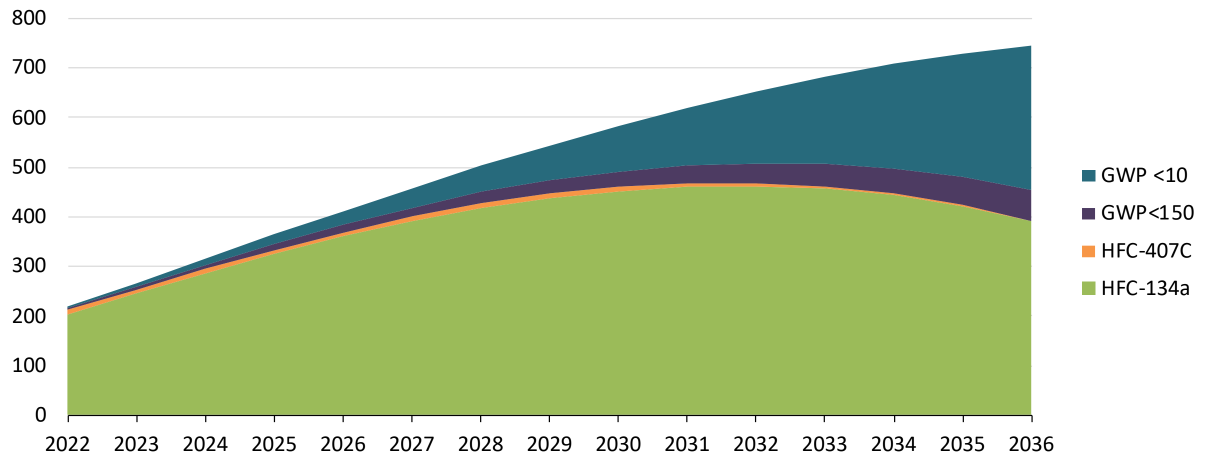
The volume of HFCs imported in HPCDs has increased significantly from 8.5 tonnes in 2015 to just under 50 tonnes in 2022, and the bank of controlled refrigerants contained in HPCDs on shore in 2022 is estimated at approximately 210 tonnes of HFCs.

This bank of controlled refrigerants is expected to peak at just over 485 tonnes (0.65 Mt CO_2e) in 2032-33 if the transition away from HFC-134a to HC-290 over the period continues at a steady pace.

A number of factors could result in the stock of high GWP equipment being larger than projected, including, for instance, manufacturers turning to Australia to dump stock charged with HFCs that has become excluded from other markets in the future, and falling electricity prices eroding the total cost of ownership advantage of the higher efficiency heat pumps systems.

Incentives to purchase higher star rated equipment, and promotion of the lower total cost of ownership for higher efficiency equipment with a GWP threshold limit, could help limit growth of this high GWP bank.

Figure 3: Refrigerant bank of heat pump clothes dryers from 2022 to 2036 in tonnes



Source: (DCCEEW 2023b)
GWP global warming potential **HFC** hydrofluorocarbon **HC** hydrocarbon

3.2 Domestic hot water heat pumps

3.2.1 The technology

The most common hot water heat pumps (HWHPs) are air source heat pumps that extract ambient heat from the outside air to heat water in a storage system. A HWHP is a vapour compression device, similar to a refrigerator, however it operates in reverse. There are three main configurations available in Australia:

1. Integrated systems that include a self-contained refrigeration system (typically on top) and water tank all in one, only requiring electrical and water connections.
2. Split system comprising a self-contained outdoor unit that contains all the refrigeration and working components in an outdoor unit, only requiring water connections between the outdoor unit and the water tank, and power.
3. Split system comprising two components, an outdoor unit that contains the main refrigeration components (i.e., compressor, evaporator and fan), and the condenser (heat exchanger) is located in the water tank, requiring refrigeration pipes, and typically flared connections to complete the refrigeration circuit.

The first two types are self-contained, small charge systems, commonly referred to as sealed systems. These sealed systems are employed in appliances that contain a refrigerant charge of 2 kg or less, and do not require any work to be done on the refrigeration system at the time of installation (AIRAH and IRHACE 2007). All of the above heat pump types require a licensed plumber to install the hot water unit, however the third type also requires a licensed technician with a refrigerant handling licence to install.

The very large majority of HWHPs are stand-alone systems however there are also multi-heat pump/tank models where up to ten heat pumps are incorporated into a cascade heat pump system for commercial applications that require large volumes of commercial grade hot water (for instance in hotels, commercial kitchens, and hospital applications).

Water source and ground source heat pumps are also available however are generally not commercially viable for residential and typical commercial office hot water applications.

3.2.2 The market and sales projection

The Australian hot water systems market has long been dominated by gas and electric resistive systems, with gas instantaneous and electric storage hot water systems being the most common. The market is estimated at between 850,000 to 1,000,000 units sold in 2022, with 80% to 85% sold into the residential market.

Gas instantaneous systems account for around 30% to 35% of the market while electric systems account for 35% to 40% of the market. Gas storage hot water systems are the third most popular type, making up around 15%, and solar gas boosted or solar electric boosted accounting for around 6% of units sold.

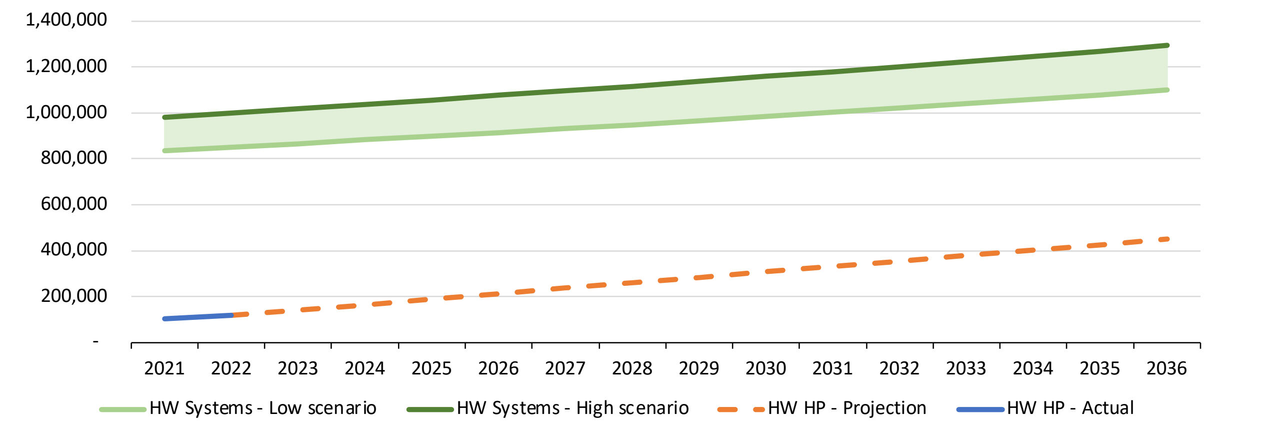
Gas instantaneous and electric storage hot water systems have been the incumbent technology since the 1960s, are most familiar to builders and trades, with well-established supply lines, some well-known Australian brands, and reliable performance that, if appropriately sized to the situation, can generally provide adequate hot water on demand. Gas storage hot water systems are also popular due to their reliability and affordability. Solar gas or solar electric hot water systems have been slowly gaining in popularity due to their environmentally friendly nature and energy cost savings over time.

Hot water heat pump (HWHP) systems, which are a much newer technology, are once again gaining traction in the market. Just prior to 2010 domestic HWHP annual sales in Australia peaked at over 72,000 units per annum (CER 2023) but due to changes to the renewable hot water rebate steadily declined to average around 20,000 per annum from 2017 to 2019. This early market behaviour very clearly illustrated the effect of the valuable financial incentive provided by the original renewable hot water rebate, which had been a significant factor in early sales growth.

The recent introductions of new financial incentives to install heat pumps in Victoria, NSW, and SA has resulted in installations of HWHPs increasing more than fourfold from the 2019 low to an estimated 100,000 units sold in 2021, and 117,000 in 2022 (CER 2023, DCCEEW 2023c, Industry sources).

This product category is expected to continue to grow strongly over the next decade and increase to around 450,000 HWHP sold in 2036. This projection of strong growth is illustrated in Figure 4.

Figure 4: Sales Projection by units of the Australian hot water market and hot water heat pumps from 2021 to 2036



Source: (CER 2023, DCCEEW 2023b, DCCEEW 2023c, Industry sources)

HWHP Hot water heat pump

The current hot water systems market is estimated at 850,000 to 1,000,000 units and is expected to grow at around 1.8% per annum over the next decade which is consistent with the growth of private dwellings. In 2021 the total number of dwellings is estimated at 10.873 million private dwellings (ABS 2022), assuming 85% of the hot water market is residential, the average lifespan of hot water systems is 12 to 15 years. HWHPs could achieve around 40% of the market by 2036. The most difficult market for HWHPs to penetrate is the apartment market, whereas free standing homes, duplex homes, town houses and dwellings with room for a water tank in the garage and a location for the condensing unit outside are opportunities more accessible to heat pumps. There was 82,595 HWHP installations that received STCs under the Renewable Energy Target scheme in 2022 (CER 2023). Assumed 10% compound growth from 2022 to 2036.

3.2.3 New sales mix projection

Multiple sources were reviewed to assess the typical charge size and refrigerant mix including:

- Pre-charged equipment (PCE) import data to assess the historical charge species and size from 2012 to 2022.
- Technical data sheets of around 50 models, particularly those locally manufactured or containing a non-controlled substance (i.e., HC-290 or CO_2).
- The registers of accredited products under the Victorian Energy Upgrades program and NSW Energy Security Safeguard scheme. As of the end of April 2023, these registers contained 197 models across 40 brands (excluding multi-heat pump/multi-tank models where up to ten units are incorporated into a cascade heat pump system for commercial applications).

The dominant refrigerant from 2015 to 2020 was HFC-134a (GWP of 1430) accounting for more than 90% of units, and the average charge over that period was 940 grams (thus 1.28 tonnes CO_2e in each device). The largest refrigerant charge for a single unit on the Victorian and NSW registers was 2.8 kg of HFC-134a.

The recent surge in sales since 2020 has had the perverse effect of models being rushed into the market to meet demand operating on around 900 grams of HFC-410A (GWP of 2088 thus 1.87 tCO_2e in each device).

In 2021 and 2022 around 30% of models installed contained HFC-410A. The assessment found that in the same period approximately 9% of models contained HC-290, 10% contained CO_2 refrigerant, 3% contained HFC-32 and the balance of around 48% was HFC-134a. This perverse effect is expected to cease to exist with future installations as the key suppliers of HFC-410A models appear to be migrating to HC-290.

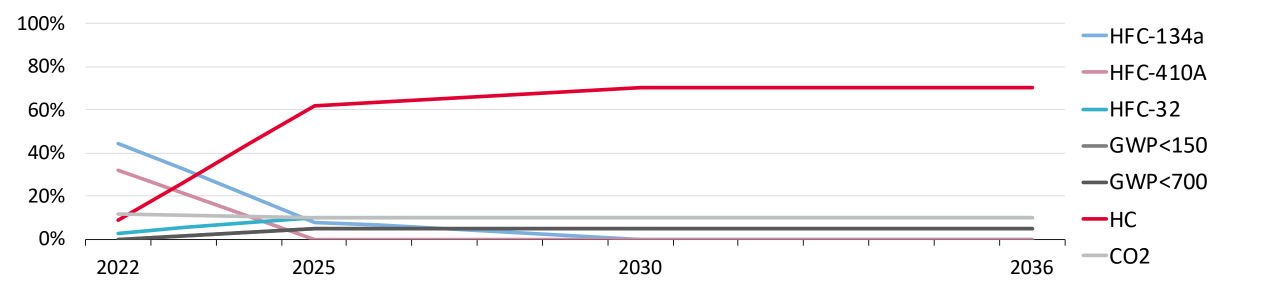
Figure 5 provides the new sales mix projection which forecasts that HC-290 will be the dominant refrigerant accounting for around 70% of installations by 2036. We anticipate there may be some suppliers that will choose HFC-32, and a smaller portion of suppliers may transition to refrigerant with a GWP less than 700 such as HFC/HFO blend R513A (GWP of 629) which is a relatively simple change from HFC-134a. A refrigerant being considered by some manufactures for the European market is HFC/HFO blend R454C (GWP of 148).

Products containing CO_2 refrigerant are predicted to grow with the market and maintain around 10% of total sales out to 2036. While products containing CO_2 refrigerant are generally the most efficient domestic hot water heat pumps available on the market, the barriers holding back growth are the relatively high costs of these models, the co-efficient of performance can decline in higher ambient regions and water hardness will restrict penetration in some regions. Water quality is an important aspect that can influence the systems operations and functionality. In areas of poor water quality all major components in a CO_2 system will have a reduced life due to the hardness of the water. In areas with "hard water" (>200 mg/L or ppm), a water softening device must be installed to ensure that long-term, efficient operation of the system is met (Reclaim Energy 2023).

Our assessment is that the majority of HWHPs will transition to HC-290, largely driven by the GWP threshold of 700 required for a heat pump installation to qualify in the Victorian Energy Upgrades program after 1 July 2024 (DEWLP 2022b). The relatively smaller HC-290 charge size in a self-contained system located outside can be designed to satisfy the relevant Australian standards, such that the high flammability refrigerant classification of HC-290 does not present a regulatory barrier in this application. While there are at least three other plausible refrigerant gas options that would also meet the Victorian Energy Upgrades program GWP threshold (HFC-32, R513A and R454C), HC-290 is considered the most likely choice by manufacturers and importers offering compliance with the GWP 700 threshold, and any future reduced GWP thresholds, delivering improved energy efficiency and a low-cost solution in one step.

The assessment assumes that local manufacturers are most likely to transition to HC-290, therefore removing some local usage of HFC-134a.

Figure 5: New sales mix projection by units for domestic hot water heat pumps from 2022 to 2036



Source: (DCCEEW 2023b, DCCEEW 2023c)

GWP global warming potential **HFC** hydrofluorocarbon **HC** hydrocarbon

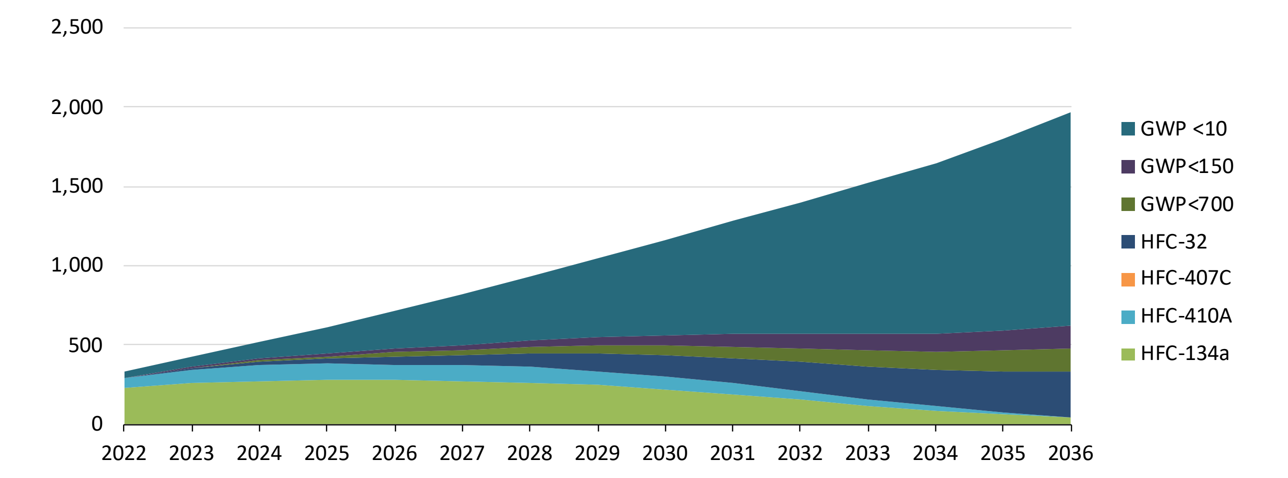
Data in Figure 5 is based on the following assumptions: The Victorian Energy Upgrades (VEU) program proposed that HWHPs with refrigerants with a GWP greater than 700 will not be eligible under the VEU program after 1 July 2024 (DEWLP 2022b). EU F-Gas Regulations is proposing a ban on air-to-water split systems with a rated capacity up to and including 12 kW, operating on HFCs with a GWP of 150 or more (except when required to meet safety requirements) from 1 January 2027. Products sold in the EU are different to those sold in Australia, therefore this regulation is not expected to greatly influence refrigerant choice of products sold in Australia. The GWP<700 line illustrates the prediction for R513A, and GWP<150 illustrates R454C which are identical. Projections of new sales mix inputs are in units installed and are based on linear projections by species in periods from 2022 to 2025, 2025 to 2030 and 2030 to 2036. These sales mixes are multiplied by respective charge sizes by year to provide new sales mix outputs by refrigerant mass.

3.2.4 Bank projection

The bank of controlled refrigerants contained in HWHPs in 2022 is estimated at under 300 tonnes and is expected to grow to over 620 tonnes (0.38 Mt CO_2e) by 2036, providing the rapid switch to HC-290 occurs as predicted in 2024 to 2025. This transition is illustrated by the large teal colour wedge for less than 10 GWP in in Figure 6.

However, if this did not occur and all the HC-290 models transitioned to HFC-32 (GWP of 675) instead by 2025 plus the same portion of CO_2 models, the HFC bank would grow significantly to over 2,500 tonnes (1.65 Mt CO_2e) in 2036. This example illustrates the importance of the Victorian Energy Upgrades program GWP ban which would provide greater surety if a national ban was imposed on this equipment class.

Figure 6: Refrigerant bank of hot water heat pumps from 2022 to 2036 in tonnes



Source: (DCCEEW 2023b)

GWP global warming potential **HFC** hydrofluorocarbon **HC** hydrocarbon

3.3 Swimming pool heat pumps

3.3.1 The technology

Traditional pool and spa heating technologies for residential and small commercial applications include solar heating, gas-fired heaters that mostly use piped natural gas as the fuel source, and relatively inefficient electric resistive heating mostly used on injection moulded plastic spas. More recently heat pumps have gained popularity in both domestic and commercial applications providing higher efficiencies and solutions to some challenges presented by solar and gas technologies.

Of the four technologies, solar heating is typically the lowest cost to operate and has the least environmental impact (Ausgrid 2015). However, each competing technology has its advantages, and disadvantages.

While providing superior energy efficiency and running costs, solar heating technology has some drawbacks. To provide adequate and efficient heating, a solar heater requires a collector that covers a large roof area with the correct aspect, which can be as much as 100% of the pool size, is costly to install and, in recent years, competes for roof space with photovoltaic solar panels. In addition, solar heating systems are entirely weather dependent, therefore they are not able to operate overnight and are limited by cloud, and shade. Even in ideal conditions these systems are slow to heat, generally requiring days or up to a week to reach a desired temperature and require the use of a pool blanket to maintain the heat efficiently.

Gas heaters are reliable and effective, they provide prompt, on demand heating all year round and are commonly used in spa pools as they can rapidly achieve the desired temperature in these smaller volume applications. The biggest downside of this technology is the higher operating costs compared to solar systems and of course they require access to natural gas. While being significantly faster, more compact, and reliable than the weather dependent solar systems, gas furnaces are significantly costlier to run and therefore uneconomical for frequent use and for large pools.

Swimming pool heat pumps are gaining popularity as they are relatively energy efficient, do not require a gas connection, and can operate year-round irrespective of the weather. A swimming pool heat pump operates in a similar way to a reverse cycle split system air conditioner except they typically have a plate or tube within a tube heat exchanger to transfer the heat to the pool.

A pool heat pump works by drawing warm air into the heat pump's evaporator coil via the evaporator fan. The air heats up the liquid refrigerant inside the system, turning it into a gas. The refrigerant gas then passes through a compressor, creating very hot gas that then passes through the condenser (heat exchanger). The condenser transfers the heat from the hot gas to the cooler pool water circulating through the heat exchanger. The heated water then returns to the pool. The hot refrigerant gas, as it flows through the condenser coil, is cooled, returns to liquid form and back to the evaporator, where the whole process begins again. Unlike alternative technologies, pool heat pumps can be used in high ambient applications to cool the pool.

In summary, solar heating has the lowest running costs as it may only require a 500 to 750 Watt circulation pump to run for 8 hours a day on average, compared to a 15 kW to 20 kW heat pump for a typical 50,000 litre pool. Where heat pumps are particularly cost effective is in situations where the pool owner has essentially free electricity during high insolation days if they have photovoltaic panels installed on their home.

While some heat pump suppliers claim coefficients of performance of more than five, it is difficult to verify these claims as there are no energy efficiency measures for swimming pool and spa pool heat pumps in Australia. The only efficiency measures associated with pools are for pumps (i.e., filtration and other) that are required to meet Minimum Energy Performance Standards (MEPS) and display an Energy Rating Label.

3.3.2 The market

There are approximately 1.2 million residential swimming pools in Australia in 2023 (Roy Morgan 2018), this number is projected to increase to over 1.5 million residential pools by 2036, assuming the same compound annual growth rate of 1.85% as private dwellings.

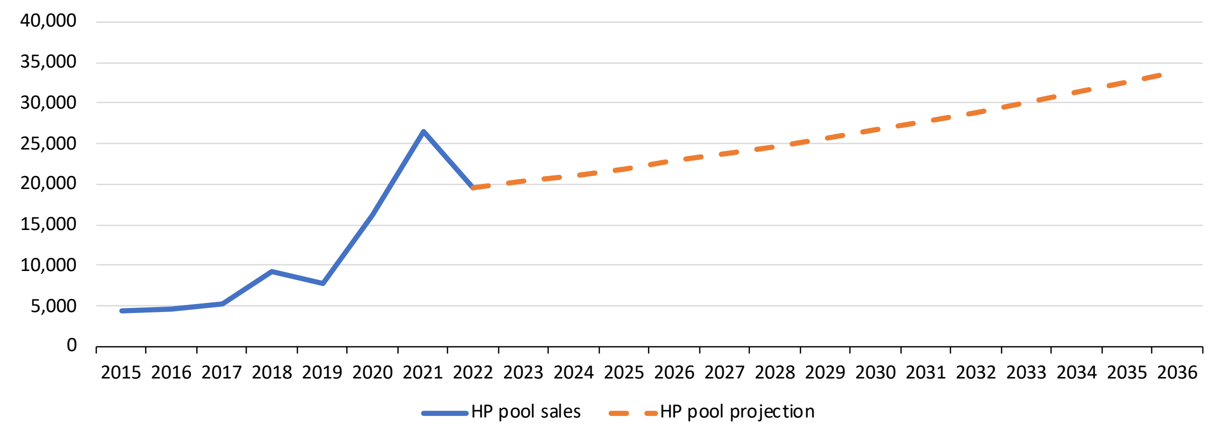
The Equipment Energy Efficiency Program, an initiative of the Australian and New Zealand governments, estimated there was approximately 1.1 million residential pools in Australia in 2018 with around 160,000 to 170,000 pool filtration pumps sold in 2018 (Commonwealth of Australia 2019). Sales of pool and spa heaters is likely to be significantly less than filtration pumps as not every pool requires a heater, however this does demonstrate there is significant potential for growth of heat pumps due to growth in pools fitted with heating and substitution of heating technology from solar and gas systems to heat pumps.

The charge sizes and capacities ranged from very small heat pumps under 5 kW, with HFC refrigerant charge sizes starting at 100 grams, to larger commercial equipment that can exceed 35 kW with a HFC charge of 20 kg (DCCEEW 2023c). The very small charge heat pumps are used on smaller, inflatable, and above ground pools and are predominantly found listed for sale on online marketplaces.

Figure 7 shows historic data for swimming pool heat pumps from 2015 to 2022 and projected sales from 2023 to 2036. Sales of swimming pool heat pumps grew at an average compound rate of 24% per annum from 2015 to 2022. Pre COVID-19 sales averaged growth of 15% per annum from 2015 to 2019 before sharply increasing by 64% from 2020 to 2021 as swimming pool sales peaked during the COVID-19 pandemic lockdowns (Razaghi and Redman 2023) before subsiding to around 20,000 imports in 2022.

3.3.3 Sales projection

Figure 7: Sales Projection by units of swimming pool heat pumps from 2021 to 2036



Source: (DCCEEW 2023b, DCCEEW 2023c)
Assumes 4% compound growth factoring in 1.85% growth in private dwellings, as well as 2.15% for the replacement market, substitution of other heating types and existing pools currently without heating. Assumes pre-charged equipment import quantities are the same as sales.

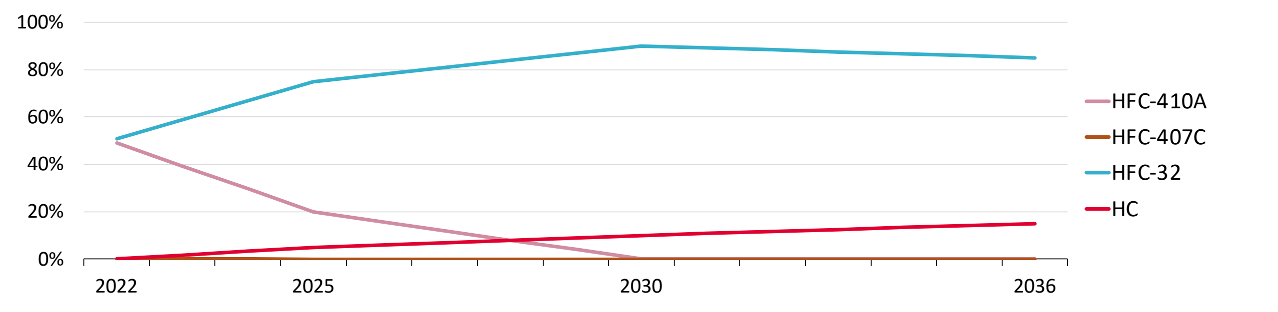
3.3.4 New sales mix projection

Assessment of historic pre-charged equipment (PCE) data from 2015 to 2022 indicates a gradual transition from HFC-410A, which has dominated as the refrigerant employed in swimming pool heat pumps, to an increasing frequency of HFC-32 charged imports.

A small quantity of units are offered with HFC-407C however this number is negligible and imports are not expected to continue. Although hydrocarbon HC-290 is commonly found in other heat pump technologies, such as clothes dryers and hot water systems, the same was not seen in pool heat pumps until early 2023 when the first product range was introduced to the Australian market by a single supplier (Supreme Heating 2023). Over 95% of all pool heat pumps imported in 2015 were charged with HFC-410A, although this figure has steadily fallen to just under 50% by 2022 as HFC-32 imports simultaneously increased.

Current data indicates that a majority of heat pump units with smaller capacities and charge sizes averaging less than 950 grams have now transitioned to HFC-32, while units with larger capacities and charge sizes averaging 1.5 kg have mostly remained on HFC-410A. Based on this historic trend, Figure 8 shows the projected new sales mix by refrigerant type. Manufacturers currently using HFC-410A are expected to transition largely to HFC-32 by 2036, and hydrocarbon HC-290 is expected to gain some market share, however in the absence of regulatory pressure encouraging a stronger shift to hydrocarbons and lower GWP refrigerants, HFC-32 is expected to dominate as the refrigerant of choice for pool heat pumps.

Figure 8: New sales mix projection by units for swimming pool heat pumps from 2022 to 2036



Source: (DCCEEW 2023b, DCCEEW 2023c)

GWP global warming potential **HFC** hydrofluorocarbon **HC** hydrocarbon

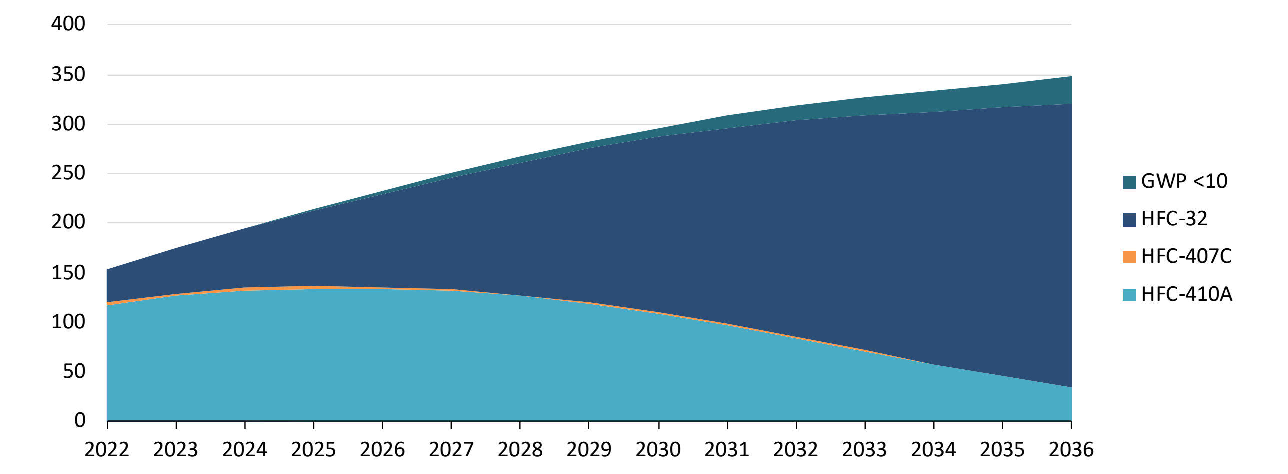
Assumptions: No new regulations will be introduced requiring the use of lower GWP refrigerants for swimming pool pumps. Technological improvements will see larger pool heat pumps with greater charge sizes transition onto HFC-32. Projections of new sales mix inputs are in units installed and are based on linear projections by species in periods from 2022 to 2025, 2025 to 2030 and 2030 to 2036. These sales mixes are multiplied by respective charge sizes by year to provide new sales mix outputs by refrigerant mass.

3.3.5 Bank projection

The bank of controlled refrigerants contained in swimming pool heat pumps is relatively small, estimated at approximately 150 tonnes, and is expected to grow to over 320 tonnes (0.27 Mt CO_2e) by 2036.

While there is one supplier offering HC-290 models, there is no regulation or commercial incentive driving suppliers to refrigerants other than HFC-32. This is why the teal colour wedge for less than 10 GWP in Figure 9 is very narrow.

Figure 9: Refrigerant bank of swimming pool heat pumps from 2022 to 2036 in tonnes



Source: (DCCEEW 2023b)

GWP global warming potential **HFC** hydrofluorocarbon **HC** hydrocarbon

3.4 Reverse cycle air conditioning

3.4.1 The technology

Small air conditioner: Room air conditioner

Air conditioners that incorporate both a heating and cooling function are heat pumps, however, they are more commonly called reverse cycle air conditioners in Australia.

The most populous segment in this category are the non-ducted split systems that cover a wide range of formats such as an outdoor unit combined with single or multiple indoor units. The indoor units can be in a variety of styles, such as wall hung, cassette, console and under ceiling units, providing a great deal of flexibility for installation and applications.

The most common format, comprising more than 90% of installations, are wall hung split single systems. The 'wall hung split' has been displacing other forms of room air conditioners and heating for more than a decade including:

- Old style window/wall air conditioners.
- Gas space heaters that can be either radiant, convection or combined radiant/convection, permanent or portable, and flued or flueless heaters.
- Solid fuel combustion heaters that largely consist of slow combustion wood heaters and burners, and
- Electric resistance that can be portable or fixed, and includes radiant, convector, fan, and underfloor heaters. Portable heaters are unlikely to transition to heat pumps due to the very low purchase cost of providing spot heating in rental properties.

Gas decorative appliances marketed as gas fireplaces or log fire style 'heaters' are also room heating sources; however, they are typically selected for ambience rather than comfort purposes.

Medium air conditioner: Multi room

The main heat pump technologies in this category are:

- Ducted split air conditioning systems, used in domestic and light commercial applications where the indoor unit is connected to rigid or flexible duct and the conditioned air is ducted around the building to supply cooled or heated air to multiple end points.
- Roof top packaged air conditioning systems, with generally larger capacities than the previous categories, and that use high static pressure fans which allow long duct runs. In recent times these systems have been redesigned with variable speed compressors (i.e., digital scroll), electric commutated plug fans, and advanced controls to improve efficiency levels to compete with other technology platforms sold into commercial buildings.
- Multi split systems with multiple indoor units that are used in residential and light commercial applications.
- Variable refrigerant volume/flow (VRV/F) split systems with a large single outdoor unit connected to multiple indoor units, which are used in larger residences, multi-story

apartments and medium sized commercial buildings (i.e., schools, multi-purpose buildings) and allow independent control of temperature at each indoor unit. Some models can provide heat recovery.

Gas ducted heaters that consist of a central furnace unit that supplies heating to different parts of the house via ducts with multiple points. Gas ducted heaters can be fitted with add on refrigerative cooling which is a cooling only air conditioner that supplies cooling through the same ducts. Gas ducted heaters are being replaced with ducted and multi split systems in many new applications, however, are more challenging to install in replacement applications.

The Victorian Energy Upgrades program introduced a new activity to assist with these challenges on 30 May 2023. The program offers financial incentives for installing heat pumps that switch out old gas appliances with a heat pump for space heating and cooling (i.e., single, multi split and ducted systems).

Other less common central heating systems are in-slab heaters that provide heat by electric cabling embedded in the slab and hydronic heaters that consist of a central water heater, usually a gas system, that distributes the heat via water filled pipes and radiator panels. There are now hydronic heat pump systems that are starting to displace boilers.

3.4.2 The market and sales projections

Single split system sales in 2022 are estimated to have been 1.32 million units, comprising 1.14 million non-ducted split systems and 181,000 split ducted systems. Ducted systems are growing steadily and were up by 14% compared to the average of 159,000 from 2017 to 2020. Strong growth is expected to continue in the years ahead as heat pumps replace gas appliances.

There were a further 36,000 sales of multi split systems, excluding VRV/F systems for which detailed information is not available, and around 200,000 small self-contained AC including window/wall units and portable AC.

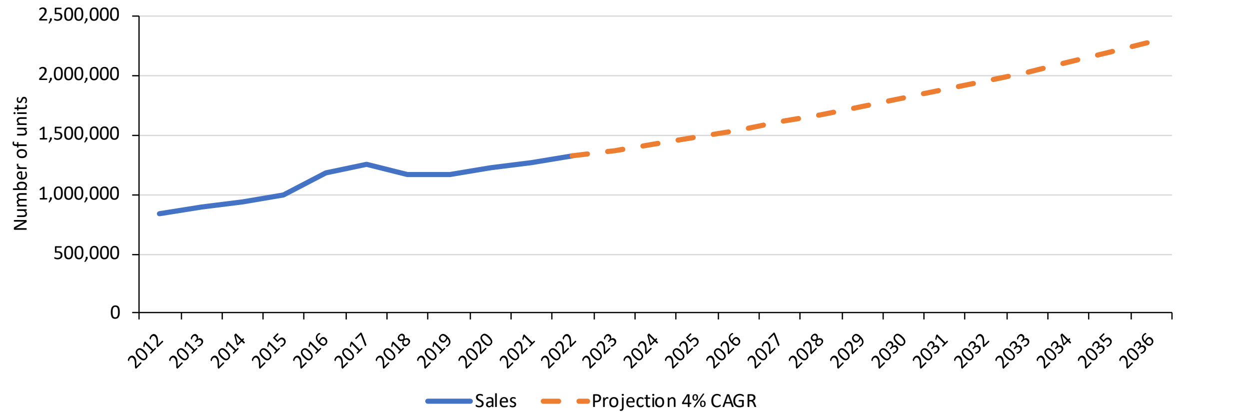
The 2021 Residential Baseline Study for Australia, RBS2.0 (DISER 2021) included 2021 sales and stock projections of mains natural gas residential heaters (excluding bottled LPG).

National sales of non-ducted gas space heaters are estimated at 50,000 with a stock of 1.3 million, and sales of gas ducted heaters are estimated at 70,000 with a stock of 1.4 million. Suppliers and contractors are already seeing significant declines of gas heater sales of more than 30%, particularly in new dwellings. It is plausible that most of these sales will transition to heat pumps over the next decade. The sales and stock of hydronic gas boilers is much smaller, estimated at around 6,500 systems sold per annum and an installed base of 150,000 units. The largest stock of gas ducted heaters is in Victoria accounting for around 85%, whereas non-ducted gas space heaters are more dispersed across the southern regions with around one third located in Victoria.

Victoria is now the second largest market behind Queensland for wall hung split systems, overtaking NSW in 2022. Some of this growth in Victoria can be attributed to replacement of non-ducted gas space heaters, driven in part by the Victorian Government Home Heating and Cooling Upgrades program that is intended to provide energy-efficient heating and cooling for low income and vulnerable households by reducing upfront cost of purchasing energy efficient reverse cycle split systems (DEECA 2023a).

Figure 10 provides an illustration of the historical sales trend of single split systems and a sales projection at 4% compound annual growth rate to 2036. The growth rate is projected to be higher than growth rates of dwellings of around 1.8% due to the substitution of gas products and replacement of less efficient older air conditioning equipment providing heating and cooling services.

Figure 10: Sales of single split systems from 2012 to 2022, and sales projection to 2036



Source: (DCCEEW 2023a, DCCEEW 2023c)
CHF Cold Hard Facts **CAGR** Compound annual growth rate.
Excludes Window/wall AC, portable AC, multi split systems, VRV/F split systems and roof top packaged air conditioning systems. Historical compound annual growth rate from 2012 to 2022 was estimated at 4.7%. The growth rate of split ducted systems may be higher than 4% CAGR depending on the rate of substitution from gas ducted heaters to split ducted systems.

3.4.3 New sales mix projection

Small air conditioner: non-ducted split systems

The pending EU F-Gas Regulations is expected to influence manufacturers' choice of refrigerant in products sold in Australia from 2029 onwards. Australia is a technology taker in this product segment, and the market leaders in the EU are similar to those in Australia with similar technology platforms operating on 220/240 Volts. The EU F-Gas Regulations (EU 2023) measures proposed are:

- A ban on single splits using HFCs with a GWP of 750 or more (in equipment with a charge of less than 3 kg) from 1 January 2025.
- A ban on air-to-air split systems with a capacity of up to and including 12 kW and operating on HFCs with GWP of 150 or more (except when required to meet safety requirements) from 1 January 2029.

The ban proposed in 2025 will not have a significant influence as more than 90% of non-ducted split systems in Australia have already transitioned to HFC-32 (GWP of 675). Major equipment suppliers acknowledge that HFC-32 is not the final end point of this technology evolution, and they expect a lower GWP alternative will emerge.

The GWP cap of 150 proposed in 2029 is expected to have a greater influence over refrigerant choice beyond this deadline. While no major equipment suppliers have provided any indication of the technical options, the current refrigerant technologies available to satisfy this ban are

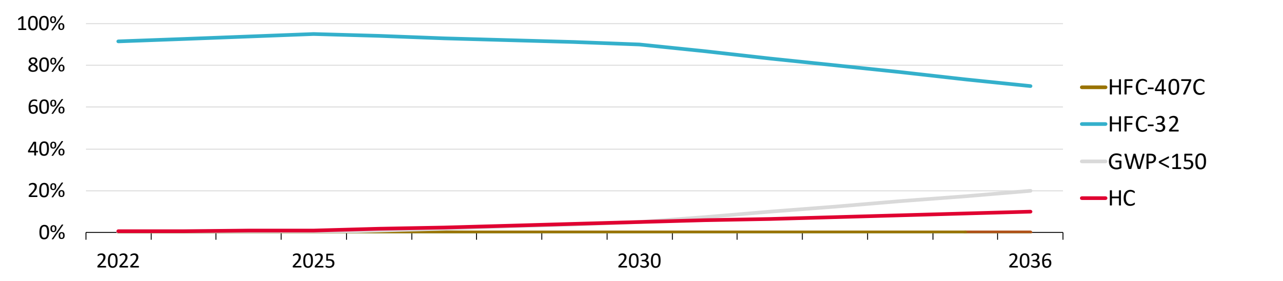
HFC/HFO Blend R454C (GWP of 148), HFC/HFO Blend R455A (GWP of 145) or HC-290 (GWP of 3).

The assessment assumes that major Japanese suppliers will be more inclined to adopt an A2L class refrigerant (i.e., HFC/HFO blend) as they have shown no signs of selecting A3 class refrigerant in the past in this type of technology. Whereas the Chinese manufactures may consider a A3 class refrigerant (i.e., HC-290) as they already offer some models in their domestic market. Alternatively, industry informants suggest that some suppliers may consider HC-290 on smaller capacity models (i.e., below 5 kW) to limit the flammable refrigerant charge.

The new method introduced on 30 May 2023 in the Victorian Energy Upgrades program for space heating and cooling has a requirement for all reverse cycle air conditioners below 15 kW to use refrigerants with a GWP of less than 700, which means that products that contain HFC-32 refrigerant will be eligible (DEWLP 2022a).

Figure 11 below provides the new sales mix projection which forecasts that HFC-32 will still account for 70% of sales in Australia by 2036 with 20% transitioning to a refrigerant with a GWP less than 150 and 10% transitioning to HC-290.

Figure 11: New sales mix projection by units for small air conditioning (single split: non-ducted) heat pumps from 2022 to 2036



Source: (DCCEEW 2023b, DCCEEW 2023c)

Assumptions: EU F-Gas Regulations is expected to influence refrigerant choice of products sold in Australia from 2029 onwards, however no technology options have been announced by major participants. Projections of new sales mix inputs are in units installed and are based on linear projections by species in periods from 2023 to 2025, 2025 to 2030 and 2030 to 2036. These sales mixes are multiplied by respective charges sizes by year to provide new sales mix outputs by refrigerant mass.

Medium air conditioner: Ducted split systems

The pending EU F-Gas Regulations are expected to influence refrigerant choice by manufacturers of products sold in Australia from 2029 onwards. The market leaders of ducted split systems in the EU are similar to those in Australia with similar technology platforms, and the refrigerant choices of Australian local manufacturers will be limited by the refrigerant options offered by global compressor manufacturers. The EU F-Gas Regulations (Cooling Post 2023e, Council of the EU 2023a) proposed measures are:

- A ban on split systems with capacities of more than 12 kW, operating on HFCs with GWP over 750 (except when required to meet safety requirements) from 1 January 2029.
- A ban on split systems over 12 kW, operating on HFCs with a GWP over 150 (except when required to meet safety requirements) from 1 January 2033.

Split ducted systems have already commenced the transition to lower GWP refrigerants with HFC-32 accounting for more than 50% of models sold in 2023. This trend is expected to continue until 2030 when we estimate 85% of models sold will contain HFC-32.

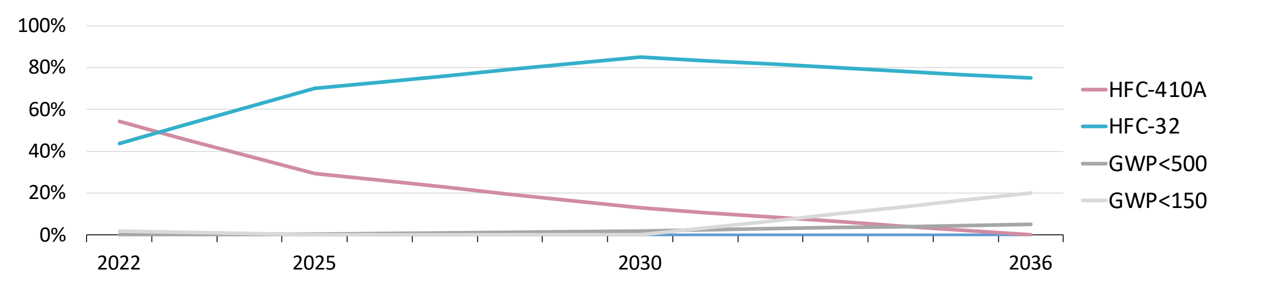
The larger charge size (i.e., >3 kg of A2L refrigerant) of split ducted systems poses a significant barrier to transition to a A3 class refrigerant (i.e., HC-290) and we do not consider hydrocarbon to be an option for this product category under the existing range of technical standards and regulations.

HFC-32, which is an A2L refrigerant, has somewhat paved the way for lower GWP A2L refrigerants. HFC/HFO blend R454B (GWP of 465) was being considered by some suppliers. However, given the GWP ban for refrigerants with a GWP greater than 150 proposed in 2033, suppliers are likely to step from HFC-32 to A2L class HFC/HFO refrigerant blend such as R454C (GWP of 148), HFC/HFO blend R455A (GWP of 145) or similar to satisfy this requirement.

Local manufacturers are currently transitioning split ducted air conditioning models from HFC-410A to HFC-32. The assessment assumes local manufacturing will continue throughout the projection period to 2036 growing at a similar rate to the rest of the market, and that the majority of usage will be HFC-32.

Figure 12 below provides the new sales mix projection for this equipment segment which forecasts that HFC-32 will still account for almost 75% of sales in Australia in 2036 with 20% transitioning to a refrigerant with a GWP less than 150, and 5% transitioning to a refrigerant with a GWP less than 500.

Figure 12: New sales mix projection by units for medium air conditioning (split system: ducted) heat pumps from 2022 to 2036



Source: (DCCEEW 2023b, DCCEEW 2023c)
HCFC hydrochlorofluorocarbon **HFC** hydrofluorocarbon **GWP** global warming potential
Assumptions: EU F-Gas Regulations is expected to influence refrigerant choice of products sold in Australia from 2029 onwards, however no technology options have been announced by major participants. Projections of new sales mix inputs are in units installed and are based on linear projections by species in periods from 2023 to 2025, 2025 to 2030 and 2030 to 2036. These sales mixes are multiplied by respective charge sizes by year to provide new sales mix outputs by refrigerant mass.

3.4.4 Bank projection

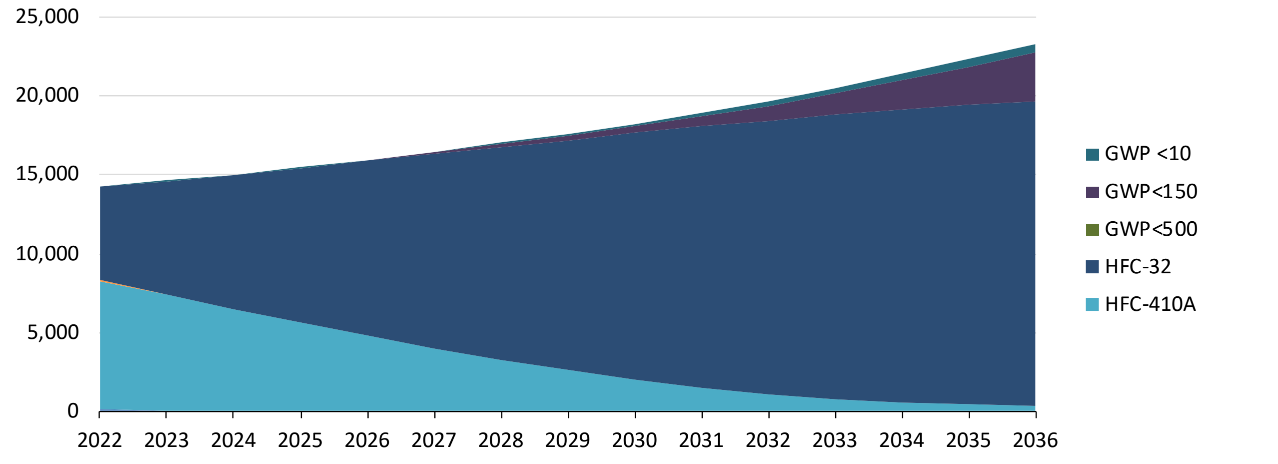
Small air conditioner: non-ducted split systems

The bank of controlled refrigerants contained in small air conditioner: non-ducted split is a significant bank, estimated at approximately 14,300 tonnes of HCFCs and HFCs in 2022, accounting for 25% of the total bank.

The revised new sales mix and growth projection estimates the bank of controlled refrigerants will grow to around 22,700 tonnes (14.2 Mt CO_2e) by 2036. This includes some models with a GWP<500 and GWP<150 illustrated by the purple wedge in Figure 13 below.

The bank projection estimates that around 19,300 tonnes will be HFC-32 (more than 82%) in 2036.

Figure 13: Refrigerant bank of small air conditioner non-ducted split systems from 2022 to 2036 in tonnes



Source: (DCCEEW 2023b)

CHF Cold Hard Facts **HCFC** hydrochlorofluorocarbon **HFC** hydrofluorocarbon **GWP** global warming potential

Medium air conditioner (excluding cooling only equipment)

Medium air conditioner (excluding cooling only equipment) includes ducted split systems, roof top packaged systems, multi-split systems and VRV/VRF split systems, and excludes cooling only equipment such as close control AC (incl. chillers) and compressed air refrigerated filter/dryers.

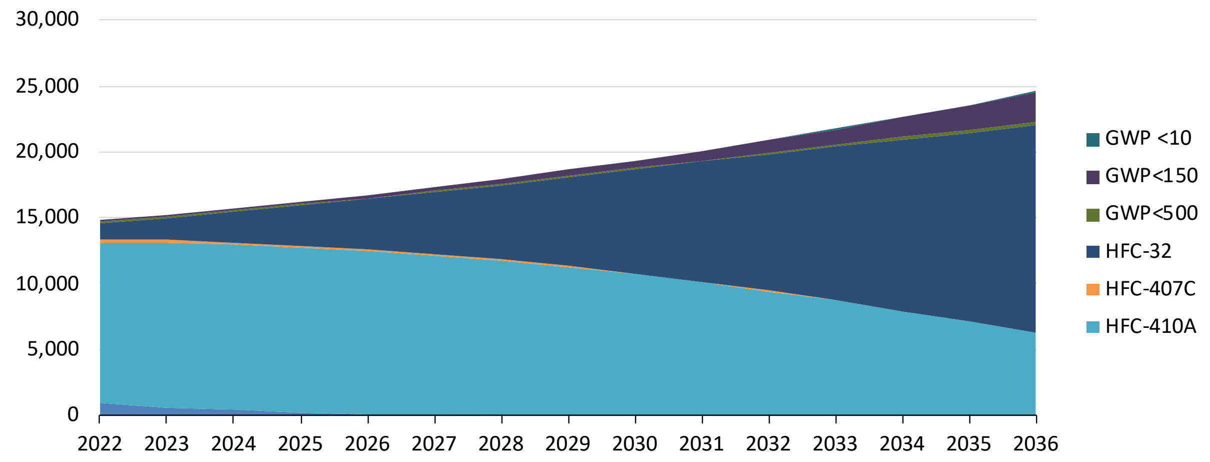
The bank of controlled refrigerants contained in medium air conditioner is the largest bank in the taxonomy, estimated at approximately 14,600 tonnes of HCFCs and HFCs in 2022, accounting for 27% of the total bank.

The revised new sales mix and growth projection estimates the bank of controlled refrigerants will grow to over 24,600 tonnes (24.2 Mt CO_2e) by 2036. This is around 1,400 tonnes greater than previous projections.

The bank projection estimates that around 15,700 tonnes will be HFC-32 (around 64%) in 2036.

Figure 14 provides an illustration of the medium air conditioner (excluding cooling only equipment) bank from 2022 to 2036.

Figure 14: Refrigerant bank of medium air conditioner from 2022 to 2036 in tonnes



Source: (DCCEEW 2023b)

CHF Cold Hard Facts **HCFC** hydrochlorofluorocarbon **HFC** hydrofluorocarbon **GWP** global warming potential

Assumptions: The above bank includes medium air conditioner categories ducted split systems, roof top packaged systems, multi-split systems and VRV/VRF split systems.

3.5 Commercial heat pumps

3.5.1 The technology

Traditionally, commercial buildings have employed separate technologies for heating and cooling.

Cooling will generally be provided by ducted air conditioning systems including either split ducted systems or roof top packaged systems, or a chiller utilising water as the heat transfer medium throughout the building. Smaller chillers have tended to be air cooled, and larger chillers water cooled, but in all instances, waste heat will be ejected to atmosphere with no re-use.

Space and water heating in commercial buildings is generally provided by gas fuelled boilers which for years have offered low installation and operating cost, as well as having the advantage of a small footprint within the building.

However, the need for buildings to become more sustainable, the post COVID-19 surge in gas prices in Australia, and the impact of global Net Zero commitments, has driven a rethink of this area.

Commercial buildings have very different heating and cooling requirements depending on their location, the climate and ambient conditions there, and the purpose of the building i.e., residential, office, retail, sports and leisure, infrastructure and medical centres. The diversity of applications in the commercial sector is being matched by new technologies, including heat pumps and multi-function chillers, that are allowing the transition away from natural gas.

Heat pumps have a single heat exchanger which is valved to allow it to perform either a heating or cooling function. When used in a heating mode, heat pumps can utilise different heat sources with ambient air being the most frequently used; however, ground sourced (geothermal) and water sourced (rivers, the sea, lakes) are also options. The heat energy available from these sources is effectively infinite and heat pumps are therefore viewed as a source of renewable energy.

Air sourced heat pumps, utilising traditional HFC refrigerants, typically heat water up to 65°C. Heat pumps utilising HC-290 can achieve temperatures of up to 75°C, and R744 (CO_2) heat pumps can operate at >90°C. Water to water heat pumps can typically achieve higher water temperatures with HFO-1234ze units reaching 85°C.

Each technology has advantages and limitations. For example, due to A3 flammability of HC-290, these heat pumps must be carefully positioned away from ignition sources and building air inlet vents and may not be suitable for all buildings. While CO_2 heat pumps can have performance limitations due to their use of the trans-critical cycle. They suffer from similar efficiency challenges in higher ambient climates to CO_2 trans-critical refrigeration systems which may limit their usage in the warmer northern latitudes of Australia. In addition, in water-to-water heating applications, the inlet water temperature typically needs to be under 30°C. If the inlet water temperature is above 30°C this tends to be outside the system operating envelope and the co-efficient of performance drops off rapidly; this creates potential complications in multi-pass applications.

Multi-function chillers are a more complex type of heat-pump that offer greater flexibility and enhanced efficiencies in their operation. A multi-function chiller has two dedicated heat exchangers, one for heating and the other for cooling; a multi-function chiller can operate in cooling mode, heating mode or can provide both heating and cooling at the same time to different services or spaces in the building, offering 100% heat recovery.

- In cooling mode, the multi-function chiller will remove heat from the building cooling water and eject the heat to atmosphere via a roof mounted condenser.
- In heating mode, the condenser will be valved to become an evaporator and the multi-function chiller will remove heat from ambient air and eject it into the heating water of the building.
- In heating and cooling mode, the multi-function chiller will remove heat from the building cooling water and transfer it into the building heating water or hot water service. In this way, 100% of waste heat from the building can be recovered and re-purposed.
- If the heating and cooling loads are not balanced, the multi-function chiller can utilise its roof mounted heat exchanger as either an extra heat source or heat sink.

The flexibility and efficiency of a multi-function chiller can be enhanced with the addition of thermal storage. Heat loads do not always balance during the day, so there is benefit in utilising additional water tanks for storage; this can be particularly helpful in low ambient temperature locations.

Multi-function chillers typically provide water temperatures up to a maximum of 65°C. If a building requires sanitary water with higher temperatures, a secondary ‘booster’ heat pump can be added to lift water temperatures to the desired level (e.g., 85°C) to cater for both general purpose hot water (washing, cleaning, drinking, and cooking), as well as space heating.

Heat pump benefits and limitations

Heat pumps have the benefit of being more efficient in their operation than gas boilers. A typical heat pump can achieve a coefficient of performance (COP) of around 3.5 in heating mode while a gas boiler may only achieve a COP of 0.8. In a commercial building application, selecting a multi-function chiller rather than a separate chiller and gas boiler solution can offer significant energy benefits. This comes from the COP advantage over gas and also the re-use of 'waste energy' from the cooling function as free heat.

Heat pumps however do have their limitations, particularly in retrofit scenarios. Gas boilers are inexpensive, compact and can be positioned in an internal plantroom; heat pumps however require roof space for heat exchangers as well as storage tanks (roof or internal) and booster heat pumps if they are required for sanitary water. Roof space in commercial buildings (particularly high rise) tends to be at a premium and often taken up by cooling towers, plant rooms, photo voltaic solar and window cleaning gantries. New buildings can be designed to accommodate heat pump technologies, but in a retrofit, space can be a real challenge. Industry sources have identified this as a major factor holding back the uptake of heat pumps in existing buildings.

Low temperatures, i.e., below minus 15°C are also a limitation for heat pumps as performance and COP drop off steeply in extremely cold conditions, and overall efficiencies are reduced below zero. However, as extremely low temperatures do not affect many regions of Australia, this lower temperature limitation is not covered in this report.

Another constraint of heat pumps that needs to be managed is defrost cycles when air source units operate in heating mode. When ambient temperatures are below 6°C and relative humidity is high, heat pump coils can freeze up and defrost cycles are required.

A defrost cycle involves reversing the refrigerant cycle so that hot gas will melt the ice on the heat exchanger; during this process, the heat pump provides no duty to the space heating task or hot water service. This issue is normally managed via multiplexing, where two or more heat pumps are used to provide the required duty rather than a single larger unit, the logic being that the units will go into defrost cycle at different times ensuring that all heating duty is not lost at any stage.

3.5.2 The market and sales projections

The potential market in commercial buildings for heat pumps covers a wide variety of applications including hospitals, airports, universities, office and retail buildings, schools, libraries, sports facilities, and aquatic centres.

However, despite the diversity of opportunity the market for commercial heat pumps is small. The commercial heat pumps sales in 2022 are estimated to have been around 250 units. Multi-function chillers are an even more immature market. Feedback from market participants suggests that annual sales volume is approximately 80 units with an average capacity of 450 kW to 500 kW per unit.

Heat pumps and multi-function chillers are increasing market share in new commercial buildings but are struggling to gain traction in retrofit applications, mostly due to space constraints and long economic payback periods.

There is also a significant market for 'process heat pumps' in industrial applications, replacing gas boilers in food manufacturing, pharmaceuticals, wineries, data centres and agricultural buildings.

Commercial heat pumps are supplied to market by most of the main equipment manufacturers including Trane, Carrier, Daikin, York (Johnson Controls), Clivet and Clint, as well as some Australian constructed systems. Multi-function chillers originated in Italy, so manufacturing tends to be European dominated, global players manufacture these units in European rather than Asian factories; large suppliers include Climaveneta (Mitsubishi Electric), Trane and Daikin.

Process heat pumps used for industrial application are far more bespoke than commercial heat pumps and are designed to match their intended use, manufacturers such as MTA and Blue Box (Swegon) are major participants in this sector.

Air source heat pumps for both water and space heating are becoming a major focus for state-based energy efficiency programs including through the Victorian Energy Upgrades program and NSW Energy Security Safeguard scheme. These programs are currently aligning their focus with State Net Zero strategies and re-focusing rebate subsides away from installing natural gas appliances to instead reward replacement of gas appliances with heat pumps. State government support is expected to drive faster commercial heat pump growth in Victoria and NSW.

Although the market is small, it is believed to have strong growth potential as gas is displaced and existing commercial buildings seek to de-carbonise (or are subsidised to do so through government initiatives). The model assumes 15% compound annual growth out to 2036, equating to more than 1,750 units being sold in 2036. Commercial heat pumps currently utilise a wide variety of refrigerant gases including traditional products such as HFC-410A, HFC-134a, HFC-407C and HFC-32, but the transition to lower GWP has started with solutions utilising HFO/HFC blends including R454C, R454B and R513A; HC-290; R744 (CO_2); R717(ammonia) and HFO-1234ze.

Projects cited by Expert Group demonstrating the use of refrigerants with a GWP less than 10 include:

- A thirty-apartment complex in Hobart, Tasmania with a 76 kW R744 (CO_2) air-to-water heat pump with two twin coil tanks and a buffer tank supplies central hot water and hydronic heating to all of the apartments.
- At quoting stage, a 150 kW HC-290 multifunction chiller proposed for a winery near Melbourne, Victoria. The multi-function chiller will cool glycol for circulation through jacketed vessels, and then re-purpose the heat for domestic hot water and 30°C process water used to warm fermentation tanks.
- A major supermarket chain has conducted trials of both HC-290 and CO_2 air-to-water heat pumps for space heating and cooling in Victoria. Heat Pumps are being trialled as an efficient alternative to existing electric duct heaters and separate ducted, refrigerated air conditioning. The units trialled have nominal capacities ranging from 150 kW to 200 kW depending on store size and contained refrigerant charge sizes of approximately 12 kg for the HC-290 models and 22 kg for CO_2 models.

- A 300 kW water to water, screw heat pump installed at a university premises in Queensland operating on HFO-1234ze. The heat pump operates off the return line of the central chiller plant, providing free heating for the building hot water service at 75°C to 85°C. HFO-1234ze was selected due to its low GWP and ability to provide higher water temperatures than similar refrigerants such as HFC-134a.
- Hardwick Processors recently installed a 1 MW water-to-water heat pump with an ammonia charge in its meat processing facility in Kyneton, regional Victoria. Australian Renewable Energy Agency (ARENA) part funded the project to demonstrate heat pump technology powered by renewable energy to manage industrial process heat demand. The existing process comprised a large ammonia refrigeration plant providing cold storage; and gas boilers for water heating used for wash down, sterilisation and cleaning purposes (some processes require water temperatures above 80°C). The new water-to-water heat pump provides heat recovery utilising the waste heat from the refrigeration plant to heat the wash down water up to 75°C. The gas boilers are now only used in a booster format to heat the water to the required 82°C and provide the balance of energy when water heating demand exceeds the heat rejection from the refrigeration plant. The heat pump installation has been combined with 2.5 MW of photo voltaic solar and 2 MW battery storage. Overall, the upgrade has resulted in an estimated 30% to 45% reduction in grid electricity usage through self-generation and a 75% drop in natural gas usage due to the new heat pump (ARENA 2023).

The HC-290 installations identified were independently assessed at the request of the end user to ensure the conditions of control satisfy *AS/NZS 60079.14:2022, Explosive atmospheres design selection, erection and initial inspection (IEC 60079-14:2013 (ED.5.0) MOD), and compliance with AS/NZS 5149 Parts 1 to 4, Refrigerating systems and heat pumps - Safety and environmental requirements.*

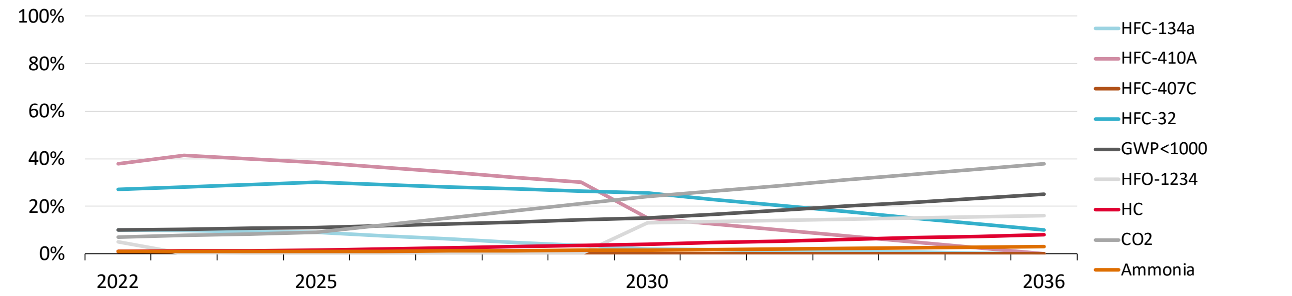
3.5.3 New sales mix projection

The commercial heat pump market is complex as it encompasses air-to-water, water-to-water, ground sourced and multi-function technologies. Interviews with market participants and analysis of available heat pump models identify that the dominant refrigerants in use are currently HFC-410A, HFC-134a and HFC-32 which account for around 75% of the market. However, R744 (CO_2), HFO-1234ze and R454B are all catching on as lower-GWP solutions and already account for around one fifth of this small specialised market. Although lower GWP working fluids are a sustainability priority for some customers, R744 and HFO-1234ze also have real technical merit in water heating applications as they can achieve higher water temperatures than mainstream products such as HFC-410A; HFO-1234ze in particular provides an excellent solution for heat pump boosters working in conjunction with multi-function chillers to provide higher water temperatures.

A substantial volume of commercial heat pumps, especially multi-function chillers are installed in new buildings that are built to achieve a sustainability rating through ‘green buildings’ schemes such as National Australian Built Environment Rating System (NABERS) or Green Star. These schemes have historically focussed on ‘operational carbon’ emissions from buildings, but this is now evolving toward a focus on ‘embodied carbon’ which factors in the carbon emissions from the manufacture of the materials within a building. The Green Building Council of Australia who administers Green Star claim that 80% of these emissions are generated upfront when the building is built. Since 2020 all new buildings seeking a Green Star rating have needed to demonstrate a 10% reduction in embodied carbon. By 2030, the benchmark will be a 40% reduction in embodied carbon (GBCA 2022). The refrigerant choice in building heating and cooling systems is recognised in embodied carbon calculations and these schemes are likely to give further impetus to the transition to lower GWP working fluids.

Figure 15 below provides the new sales mix input projection which forecasts the transition away from HFC-410A and HFC-134a, initially in favour of HFC-32, HFO-1234ze, R744 and R454B. It is projected that between 2030 and 2036, HFC-410A and HFC-134a installs will cease and that HFC-32 will also decline sharply. HC-290 is expected to slowly grow as a refrigerant in commercial heat pumps as manufacturing standards mature, technician training increases and market confidence grows in its ability to be safely utilised. By 2036 it is projected that the commercial heat pump market will be dominated by R744 (CO_2), HFO Blends, HFO-1234ze and HC-290.

Figure 15: New sales mix projection by units for commercial heat pumps from 2022 to 2036



	2022	2025	2030	2036
HFC-134a	10%	9%	2%	0%
HFC-410A	38%	39%	15%	0%
HFC-407C	1%	0%	0%	0%
HFC-32	27%	30%	26%	10%
GWP<500	10%	11%	10%	15%
GWP<150	0%	0%	5%	10%
HFO-1234	5%	0%	13%	16%
HC	1%	2%	4%	8%
CO_2	7%	9%	24%	38%
Ammonia	1%	1%	2%	3%
Total	100%	100%	100.0%	100%

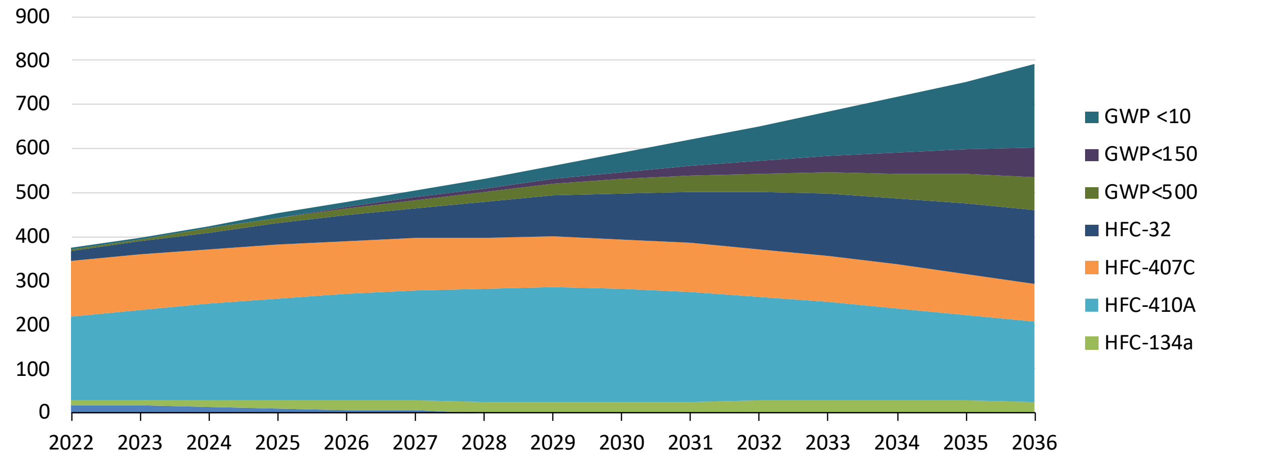
Source: (DCCEEW 2023b, DCCEEW 2023c)
HCFC hydrochlorofluorocarbon **HFC** hydrofluorocarbon **GWP** global warming potential
Assumptions: Installations of commercial heat pumps are engineered solutions where refrigerant type is considered in the design and selection process. Projections of new sales mix inputs are in units installed and are based on linear projections by species in periods from 2023 to 2025, 2025 to 2030 and 2030 to 2036. These sales mixes are multiplied by respective charge sizes by year to provide new sales mix outputs by refrigerant mass.

3.5.4 Bank projection

The commercial heat pump bank is one of the most diverse banks with a very diverse mix of technologies and refrigerants. The technology transition away from gas is in its early stages and the bank of controlled refrigerants is relatively small, estimated at approximately 370 tonnes in

2022. This bank of HFCs and HFO blends is expected to grow to around 600 tonnes (0.83 Mt CO_2e) by 2036.

Figure 16: Refrigerant bank of commercial heat pumps from 2022 to 2036 in tonnes



Source: (DCCEEW 2023b)
GWP global warming potential **HFC** hydrofluorocarbon **HC** hydrocarbon

3.6 Other heat pump technologies

There are a wide variety of heat pump products available. This section provides a list of products that are sold in smaller quantities, they include:

- Air-to-water heat pumps that provide hydronic heating and residential hot water with some models offering cooling via a floor console evaporator. They are generally made up of different configurations of outdoor units, indoor units and water tanks. These types of systems have gained significant attention in recent years in Europe. The monobloc systems, that contain all the refrigeration and working components in an outdoor unit, facilitate migration to A2L mildly flammable and H3 flammable refrigerants as well as allowing more efficient use of indoor space. Sales of these products are not expected to grow to more than one to two percent of the overall air conditioning market by 2036.
- Ultra-low temperature air source heat pumps developed to operate in cold climates down to minus 15°C. While there may be some opportunities to substitute gas in Alpine and cold regions of Australia with this technology, the annual volumes are not expected to be significant.
- Some commercial dry-cleaning equipment incorporate heat pumps. There were less than 200 units identified in pre-charged equipment import data over the period from 2015 to 2022. Most models contained HFC-407C with some operating on HFC-410A with average charges of 4 kg to 5 kg.
- Clothing care systems discussed in Section 3.1.3.
- District heating and cooling infrastructure found in Europe and other regions that can offer great potential for efficient, cost-effective and large-scale integration of low-carbon energy sources, including waste heat and renewable sources such as geothermal, solar and biomass. District heating systems are unlikely to be adopted in Australia.

- Water source and ground source hot water heat pumps, and industrial applications with water temperatures > 85 degrees) discussed in Section 3.5.

4 The risks of emerging heat pumps

4.1 Potential impacts on the HFC phase down

The projected increases in sales of heat pumps are not expected to have a significant impact on the HFC phase down compared to previous projections.

The main reasons are:

- Heat pump clothes dryers and domestic hot water heat pumps are sealed units with very low leak rates and are unlikely to consume refrigerant during servicing unless there is a major product recall, and the supplier elects to repair rather than replace. At present the importers of product have limited ability to undertake repairs.
- Sales of pool heat pumps and commercial hot water heat pumps are relatively small.
- Single split, multi-split or ducted systems are already a well-established heat pump technology with an estimated at 1.32 million units sold in 2022, and the recent projections only represent an additional 2% to 3% compound annual growth in sales out to 2036.
- For example, the bank of small air conditioner: non-ducted split is currently estimated at almost 12 million units containing around 8,100 tonnes of HFC-410A and almost 4,800 tonnes of HFC-32, therefore an additional 2% to 3% sales growth of mostly HFC-32 models over the next 14 years to 2036 is not statistically significant compared to the large existing bank. Similarly with Medium air conditioner category that currently has a large existing bank of more than 10,900 tonnes of HFC-410A equipment.

The estimate of the 'additional' impact on the HFC phase down from the increasing growth in the sales of heat pumps included the following analysis:

- Assumed CHF2022 stock model was the baseline position that included modest growth in the stock of heat pumps out to 2030, already apparent in the economy prior to 2021.
- The CHF2022 stock model provided refrigerant usage projections out to 2030, these projections were extended out to 2036 assuming a best-fit linear trend line for the total emissions and all major heat pump categories being assessed. Refer baseline usage in the table in Figure 17.
- The additional sales and emissions were calculated in an updated stock model HP2023 for each major heat pump category being assessed to understand the additional emissions impact due to the higher projected growth.

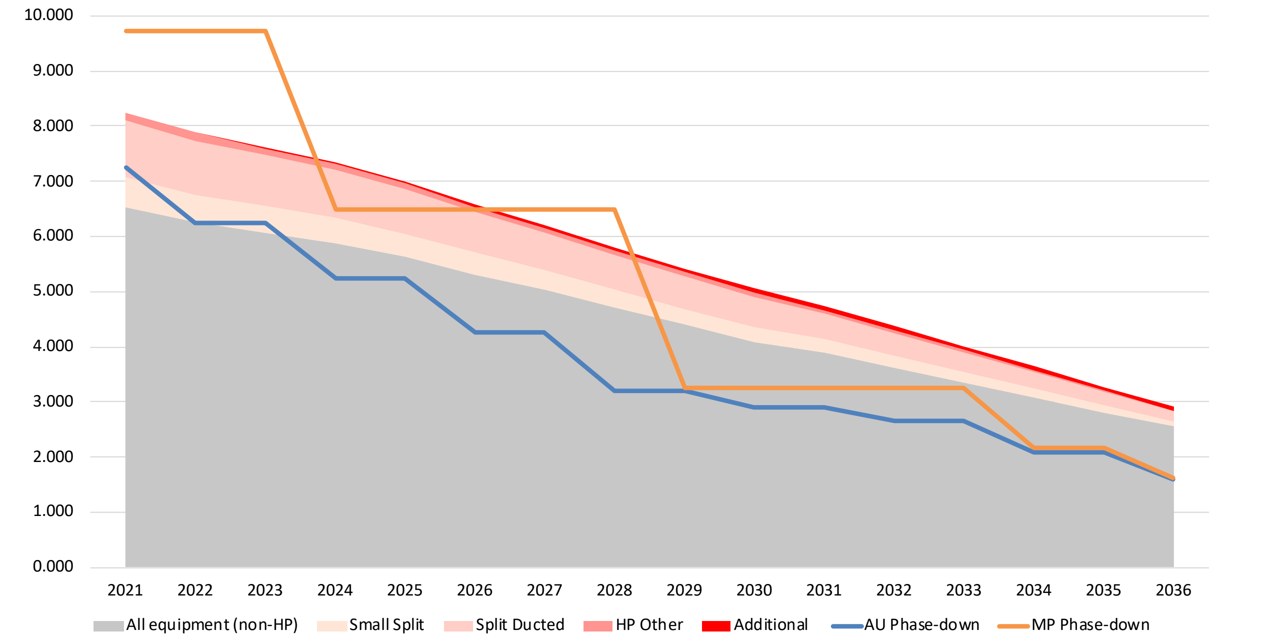
The additional usage projection from emerging heat pumps is illustrated by the top thin red wedge in Figure 17 with the values in Mt CO_2e and percentages noted in the table. Observations of the assessment are as follows:

- The additional HFC usage from the surge in heat pumps is estimated to add up to 0.071 Mt CO_2e in 2036, equating to around 4.4% of the Montreal Protocol limit of 1.622 Mt CO_2e in 2036 (4.4% of the Australian phase down schedule of 1.607 Mt CO_2e in 2036).
- There are many assumptions in the estimate, including sales projections, new sales mix refrigerant projections, usage and refrigerant mix of local manufacturing, average

charges, and service rates of classes of equipment. The 4.4% is considered an upper limit, and the lower limit is estimated at around 0.048 Mt CO_2e equating to around 3.0% of the Montreal Protocol limit of 1.622 Mt CO_2e in 2036.

- While the surge of heat pumps presents some risks to the HFC phase down, the historical air conditioning equipment classes, commercial refrigeration and mobile air conditioning pose far greater risks, and greater opportunities to lower refrigerant usage to meet the Montreal Protocol commitments.
- Australia started a gradual phase down of HFC imports from 1 January 2018. Consumption is estimated to be 2.6 Mt CO_2e above the Australian phase-down schedule in 2028 on present trends.
- The most challenging Montreal Protocol control point will be in 2029, where usage is predicted to be 2.2 Mt CO_2e (65%) above the cap.
- The projected HFC usage does not take refrigerant recovery, drop-in replacement activity and recycling into account.

Figure 17: HFC Phase down steps and refrigerant usage from 2022 to 2036 in Mt CO_2e



	2022	2024	2026	2028	2030	2032	2034	2036
	Refrigerant usage (Mt CO_2e) projections							
All equipment (non-HP)	6.25	5.89	5.32	4.72	4.08	3.63	3.09	2.55
HP Other	0.14	0.12	0.10	0.08	0.07	0.05	0.03	0.01
Small Split	0.51	0.45	0.38	0.32	0.27	0.20	0.14	0.08
Split Ducted	0.98	0.86	0.74	0.61	0.56	0.42	0.31	0.20
Total baseline	**7.88**	**7.32**	**6.54**	**5.73**	**4.98**	**4.30**	**3.57**	**2.84**
Additional emerging HP	0.01	0.04	0.05	0.07	0.07	0.08	0.08	0.07
Total baseline plus additional emerging HP	**7.89**	**7.36**	**6.59**	**5.80**	**5.05**	**4.38**	**3.65**	**2.91**
AU Phase-down	6.25	5.25	4.25	3.20	2.90	2.65	2.10	1.61
MP Phase-down	9.73	6.49	6.49	6.49	3.24	3.24	2.16	1.62
Variance to AU Phase-down	**1.64**	**2.11**	**2.34**	**2.60**	**2.15**	**1.73**	**1.55**	**1.30**
Additional emerging HP (% of Total baseline)	0.17%	0.50%	0.83%	1.17%	1.50%	1.83%	2.17%	2.50%
Additional emerging HP (% of AU Phase-down)	0.21%	0.70%	1.28%	2.09%	2.57%	2.98%	3.68%	4.42%

Sources: (DCCEEW 2022, DCCEEW 2023b)
All equipment (non-HP) includes commercial and domestic refrigeration, mobile air conditioning, and all other equipment classes in the CHF taxonomy. **HP Other** includes heat pump clothes dryers, hot water heat pumps (domestic and commercial) and pool heat pumps. **Additional** includes emissions attributed to the additional sales in the updated stock model for each major heat pump categories being assessed. HCFCs are not included in the above chart as emissions of Ozone Depleting Substances are not counted as part of the phase-down of synthetic greenhouse gases reported under the Kyoto Protocol. The Montreal Protocol HFC baseline for Australia is 10,813,465 t CO_2e, and the control limit for 2019 is 90% of the baseline equating to 9.732 Mt CO_2e. The control limit steps down to 6.488 Mt CO_2e in 2024 which is 60% of the baseline. The refrigerant usage values in the table are rounded to two decimal places, the percentages were calculated prior to rounding, for example 0.071 Mt CO_2e as a percentage of 1.607 Mt CO_2e the AU Phase-down in 2036, is 4.42%.

4.2 Potential impact on end-of-life emissions

As appliances such as refrigerators, air conditioners, and heat pumps (i.e., clothes dryers, hot water systems and pool systems) reach the end of their useful life, they can have several significant environmental impacts. The main environmental impacts associated with the disposal and recycling of these appliances include:

Landfill waste: Appliances contain many materials that can contribute to landfill waste, including plastics, metals, and hazardous materials such as refrigerants, oils, and electronic components.

Greenhouse gas emissions: Appliances that contain chlorofluorocarbons (CFC), HCFC and HFC refrigerants, such as refrigerators, air conditioners, and heat pumps, can contribute to greenhouse gas emissions if not properly recycled. We estimate that around 1 million (additional 350,000 containing HC and CO_2) heat pump clothes dryers, hot water heat pumps and swimming pool heat pumps containing HFCs will reach end-of-life from 2023 to 2036, and the majority will go straight to land fill resulting in the entire charge being released to the atmosphere. There are an estimated 13.2 million single split non ducted air conditioners containing HFCs predicted to retire over the same period. While many of these split systems will be decommissioned by contractors with refrigerant handling licences there will be a significant portion removed and/or scrapped by people without refrigerant recovery equipment.

Resource depletion: Appliances require the use of natural resources, such as metals, plastics, and rare earth elements, in their production.

There is a wide variety of reasons remnant refrigerant is not fully recovered from the equipment that reaches the end of its life. They include economic factors and practical issues of equipment ownership, and retirement and disposal decisions. In some instances, there is no licensed technical workforce in the supply chain with the tools required to recover waste gas (e.g., refrigerators, heat pump clothes dryers and domestic hot water heat pumps).

At present, some refrigerant is collected by licensed technicians from some types of heat pumps, generally equipment with larger refrigerant charges (i.e., ducted split systems and a portion of wall hung split systems), and some landfill tips/depots collect refrigerant. However, at present Australia does not have an effective national legislative approach mandating the disposal and recycling of these appliances, resulting in very low compliance rates with the requirement to collect end-of-life refrigerants.

The rapid emergence of heat pumps presents significant environmental risks at end-of-life. Table 4 provides a summary of the refrigerant bank at the highest risk of being emitted at end-of-life.

Table 4: Risks of direct emissions from end-of-life heat pumps

Equipment category	Bank of HFCs in 2036 (Mt CO_2e)	Retirements of HFCs in 2036 (Mt CO_2e)	Level of risk of direct emissions from end-of-life equipment
Heat pump clothes dryers	0.65	0.04	High risk of refrigerant being released to atmosphere. Most of these devices have sealed refrigeration circuits that do not require a trades person with a refrigerant handling licence to decommission and will end up at scrap metal recyclers and rubbish tips/depots. While some split hot water heat pumps require a technician with a refrigerant handing licence to install, there is no certainty a licensed technician will be involved in the replacement and/or decommissioning.
Hot water heat pumps	0.39	0.06	
Swimming pool heat pumps	0.27	0.03	
Wall hung split systems	14.20	0.91	Medium risk of refrigerant being released to atmosphere. A significant portion of equipment is installed by electricians and trades people that only hold a restricted heat pump split system installation and decommissioning licence. This licence has no requirement to have the tools necessary to recover waste gas (i.e., recovery cylinder, etc.).
Single split system: ducted, roof top packaged systems, VRV/VRF split systems	25.40	1.57	Lower risk of refrigerant being released to atmosphere. Installation of this class of equipment is mostly undertaken by skilled trades people with a full refrigeration and air conditioning licence. These technicians are required to carry the tools necessary to recover waste gas (i.e., recovery cylinder, etc.) and are permitted to handle refrigerant and perform service, repair or maintenance of all types of split systems.

Source: (DCCEEW 2023b)

4.3 Premature product failure and wave of warranties

Heat pumps for space heating and cooling (i.e., single, multi-split and ducted systems) are mature products manufactured by international corporations with large scale manufacturing facilities and premature product failure is not considered a significant risk. In addition, there is a skilled workforce that has been installing over 1 million units per annum over the last decade. Similarly, the reputation and reliability of the global manufacturers supplying heat pump clothes dryers is not considered a great risk.

However, premature product failure and a wave of warranty claims that emerged in stocks of recently installed hot water heat pumps present a significant risk to homeowners and small businesses.

Several of the large suppliers operating in the state-based energy efficiency schemes that account for more than 50% of sales are focused on chasing the rebates. They have a “free giveaway” business model or at least a very low co-contribution cost of $200 to $300 by the consumer. Whereas suppliers of quality equipment may charge the consumer around $1,500 for supply and installation.

This "free giveaway" business model encourages suppliers to source the lowest cost and lowest quality products from second and third tier manufacturing companies in Asia, predominately China, which is a major concern for unsuspecting consumers.

A list of common faults currently being reported by plumbers in the field include:

- Products installed were not suitable for the premises.
- Rattling and noisy compressors.
- Compressor failures.
- Failed refrigeration circuit.
- Tanks rusted through due to poor lining.
- Rusty water from missing washers in the fittings.
- No or inadequate insulation of external pipes.
- Missing drain cocks on valves.
- Incorrect installation of the pressure and temperature relief valve.
- Inappropriate airflow clearances which directly affects energy efficiency.
- Heat pump or tanks not being appropriately secured which raises safety concerns.
- Exposed blue line polyethylene material being used and not being protected or buried (workmanship related).
- No approved point of discharge on the relief drain lines (workmanship related).
- Controller covers not being waterproof and faulting from low quality manufactured products.
- Water quality-based issues.
- Overall, the quality of the fittings and sensor cables are common areas of faults.

In addition, plumbers installing cheaper heat pumps are being squeezed on the install rates and as such they are reusing old parts which causes greater failures than would normally take place in a standard hot water replacement market.

Whilst some poor-quality products have been removed from the Victorian Energy Upgrades program's 'VEU register', more needs to be done by regulators to protect consumers from poor quality products that are failing prematurely or being poorly installed.

The Essential Services Commission who administers the Victorian Energy Upgrades program issued a harsh warning on 18 May 2023 to all accredited persons installing water heating products that the commission will take action where poor installation practices are identified, including non-compliant installations and unsafe behaviour under the program. They cautioned accredited persons that the commission has zero tolerance for non-compliant, unethical, unsafe, fraudulent or misleading behaviour by persons accredited to deliver energy efficient products and services through the program.

One of the main issues is that the warranty period can vary greatly between manufacturers, with some offering warranties as short as 1 to 2 years and others offering warranties of up to 10 years. It is important for homeowners to carefully read the warranty terms and conditions to understand what is covered and for how long. Additionally, some warranties may not cover certain types of damage, such as damage caused by water quality issues or external factors such as weather events. It is important to understand the specific exclusions and limitations of the warranty before purchasing a hot water heat pump. Finally, it is important to note that warranties may only cover the cost of replacement parts and not the cost of labour for repairs or replacement.

The scale of the environmental issue caused by low quality systems could be significant due to the sheer volumes of hot water heat pumps expected to be installed over the next decade. The current projection of hot water heat pumps based on a compound annual growth rate of 9% per annum amounts to 3.9 million appliances being installed between 2022 and 2036.

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Appendix A

Part 1 – Taxonomy of Technology

The Cold Hard Facts taxonomy of technology is a hierarchical data structure for all refrigeration and air conditioning (RAC) vapour compression applications in Australia. The taxonomy is a structure used to manage the mass of data that must be captured and analysed in the age-cohort mass balance stock model that underpins the Cold Hard Facts series of reports. The taxonomy was updated as part of this project to include the emerging range of heat pumps.

The top level of the updated taxonomy now includes 4 broad classes as follows:

Air conditioning (AC) that incorporates both cooling only air conditioning, and heat pumps that provide both space heating and cooling functions that are more commonly called reverse cycle air conditioners in Australia. The majority of the small and medium sized equipment are air-to-air heat pumps, and the larger chillers are air-to-water or water-to-water cooling only systems that are not heat pumps.

Heat pumps (HP) is a category that covers all other heat pump applications. The most numerous in this category are air source hot water heat pumps but also includes heat pump clothes dryers, pool heat pumps, multi-function chillers, and other less common types including water and ground source heat pumps, heat pump driven hydronic heating and specialised heat pump dry-cleaning equipment. The majority of the small and medium sized equipment categories are air-to-water heat pumps, except clothes dryers that are air-to-air heat pumps. The large heat pumps are mostly air-to-water systems; however, some are water-to-water and ground-to-water.

Cold chain that includes domestic, commercial, supermarket, transport, process, and industrial refrigeration.

Mobile air conditioning that includes air conditioning equipment found in passenger vehicles, light commercial vehicles, buses, trucks, and in unregistered and off-road applications.

The cold chain and mobile air conditioning classes are refrigeration and cooling only technologies and therefore not within scope of this report.

Small, sealed AC that includes window/wall units, portable AC and other small AC such as cooling for electrical switchboards are not within scope of this assignment. They are either cooling only, or reverse cycle AC that are not considered emerging or high growth heat pump technologies.

The taxonomy of technology of all air conditioning and heat pump technologies is provided in Table 5 which indicates which applications and product categories are within scope.

Table 5: Air conditioning and heat pump taxonomy of technology

Class	Segment	Application	Category code	Product category	Within scope of this assignment
Stationary air conditioning (AC) and Heat pumps (HP)	AC1: Small AC: Self-contained	Window/wall	AC1-1	Non-ducted: Unitary 0-10 kWr	No
		Portable AC	AC1-2	Portable AC and de-humidifiers 0-10 kWr	No
		Small AC other	AC1-3	Other (incl. enclosure/switchboard AC)	No
	AC2: Small AC: Split	Single split: non-ducted	AC2-1	Single split system: non-ducted (wall hung, cassette, console and under ceiling units)	Yes
	AC3: Medium AC: Ducted & light commercial	Domestic & light commercial	AC3-1	Single split system: ducted	Yes
		Light commercial	AC3-2	Roof top packaged systems	Yes
		Domestic & light commercial	AC3-3	Multi split	Yes
		Light commercial	AC3-4	VRV/VRF split systems	Yes
		Light commercial	AC3-5	Close control AC (incl. chillers)	No
		Light commercial	AC3-6	Compressed air refrigerated filter/dryers	No
	AC4: Large AC: Chillers	Chillers	AC4-1	<350 kWr	No
		Chillers	AC4-2	>350 & <500 kWr	No
		Chillers	AC4-3	>500 & <1000 kWr	No
		Chillers	AC4-4	>1000 kWr	No
	HP1: Small HP	HW heat pump: domestic	HP1-1	Hot water heat pump: domestic, incl. residential and commercial as well as cascade systems	Yes
		Heat pump clothes dryers	HP1-2	Heat pump clothes dryers	Yes
		Small heat pump other	HP1-3	Other (i.e., clothing care systems)	Yes
	HP2: Medium HP	Domestic & light commercial	HP2-1	Pool heat pumps	Yes
		Domestic & light commercial	HP2-2	Other (i.e., dry cleaning equipment, hydronic heating)	Yes
	HP3: Large HP	Light commercial and industrial	HP3-1	Commercial heat pump and multi-function chillers (air source hot water heat pumps with water temperatures ≤ 85 degrees)	Yes
		Light commercial and industrial	HP3-2	Other (i.e., water source and ground source hot water heat pumps, and industrial applications with water temperatures > 85 degrees)	Yes

Source: (DCCEEW 2023b)

Part 2 – Technical characteristics by product category

Segment	Product category	Average charge of most common species (kg) (a)				EOL factors (%) (b)		Service Rate (% of original charge) (d)	Nominal lifespan (years)
						EOL factors	Tech rec (c)		
AC2: Small AC: Split	Single split system: non-ducted (wall hung, cassette, console and under ceiling units)	**HFC-410A**	**HFC-32**	**HC-290**		80%	90%	2.5%	12.0
		1.40	1.12	0.51					
AC3: Medium AC: Ducted & light commercial	Single split system: ducted	**HFC-410A**	**HFC-32**			80%	90%	3.0%	16.0
		4.70	3.30						
HP1: Small HP	Hot water heat pump: domestic, incl. residential and commercial as well as cascade systems	**HFC-134a**	**HFC-410A**	**HC-290**	**CO_2**	85%	90%	2.0%	10.0
		1.10	0.92	0.53	0.72				
	Heat pump clothes dryers	**HFC-134a**	**R450A**	**HC-290**		85%	90%	2.0%	15.0
		0.41	0.46	0.14					
HP2: Medium HP	Pool heat pumps	**HFC-407C**	**HFC-410A**	**HFC-32**	**HC-290**	80%	90%	2.0%	12.0
		2.60	1.60	1.00	0.78				

EOL end of life.
(a) Average charge of the most common species found in that product category. Charges of other species used in the same product category may differ. **(b)** EOL factor used to calculate residual EOL charge at end of life. EOL factors generally consistent with others cited internationally and in IPCC good practice guides. **(c)** Calculated EOL charge in each segment has maximum technical recovery factor uniformly set at 90%. (**d)** The service rate of sealed units includes usage from repairs or a possibly product recall.