RACE for 2030
RELIABLE AFFORDABLE CLEAN ENERGY

Final Report

Decarbonising heat pump product development in Australian commercial and industrial sectors

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Acknowledgement of Country

The authors of this report would like to respectfully acknowledge the Traditional Owners of the ancestral lands throughout Australia and their connection to land, sea and community. We recognise their continuing connection to the land, waters and culture and pay our respects to them, their cultures and to their Elders past, present, and emerging.

What is RACE for 2030?

RACE for 2030 CRC is a 10-year co-operative research centre with AUD350 million of resources to fund research towards a reliable, affordable, and clean energy future. https://www.racefor2030.com.au

Executive summary

This report provides a technology update and investigation on the existing heat pump market for commercial and industrial (C&I) sectors in Australia. The research has shown the available temperatures for heat pumps in various sectors, in light of different technology readiness levels (TRL), are becoming available for different processes at higher temperatures, up to 280 °C.

Heat pumps are widely adopted in residential and small commercial buildings globally but are also finding more application in the industrial sector. When it comes to Australia, where the climate is considerably varied and where there are four seasons across most of the country, heat pumps are generally used in both residential and commercial settings, serving a variety of purposes including air conditioning, space heating, and domestic hot water production.

This report highlights several technological developments in high-temperature heat pumps, as well as a deep transformation of the refrigerant market towards low-global warming potential (GWP) options. The report provides a brief overview of the latest insights regarding additional solutions such as mechanical vapour recompression (MVR), CO_2 heat pumps, two-speed compressors, dual-fuel or hybrid systems and scroll compressors.

The research also investigates some key challenges in the Australian C&I heat pump market with relevant operators, highlighting main product temperature ranges, upcoming solutions in the market, refrigerants, system design challenges as well as mechanisms to support the deployment of such solutions in Australia. In particular, emphasis on exploring issues with current white certificate schemes, looking at additional considerations to be made beyond energy savings (e.g., flexibility in the system configuration) as well as sourcing products from reputable suppliers with well-established supply chains. Surveyed industry respondents advocate for more clarity regarding the ownership of the accreditation for the white certificate schemes, also in light of the distinction between code compliance and safe heat pump installation.

The research has also preliminarily discussed how a potential roadmap could address such concerns, for example through a set of different actions, including:

- the development of a high-level tool to estimate certificate values
- the availability of facility templates at varying levels of complexity
- by refocusing the purpose of the measurement and verification plan
- redefining the testing process.

Supporting the installation process with clear guidelines and proper training is critical, but the roadmap should be tailored on the specific characteristics of the commercial and industrial applications across various sectors.

Contents

1 Introduction

1.1 Background

The decarbonisation of the heating sector has emerged as a critical focal point within the energy domain, driving a surge in interest towards heat pump technologies in recent years. Owing to their demonstrated energy efficiency and negligible carbon dioxide emissions, heat pumps are increasingly recognised as a pivotal pathway to decarbonise the heating sector.

Using heat pumps to electrify heating and cooling can play an important role in delivering the Australian Government's target to reduce Australia's emissions by 43% by 2030 providing energy and emissions abatement in multiple economic sectors. Heat pumps are highly efficient and can be powered by renewable energy to meet a wide range of thermal energy needs, from heating homes to powering industrial processes.

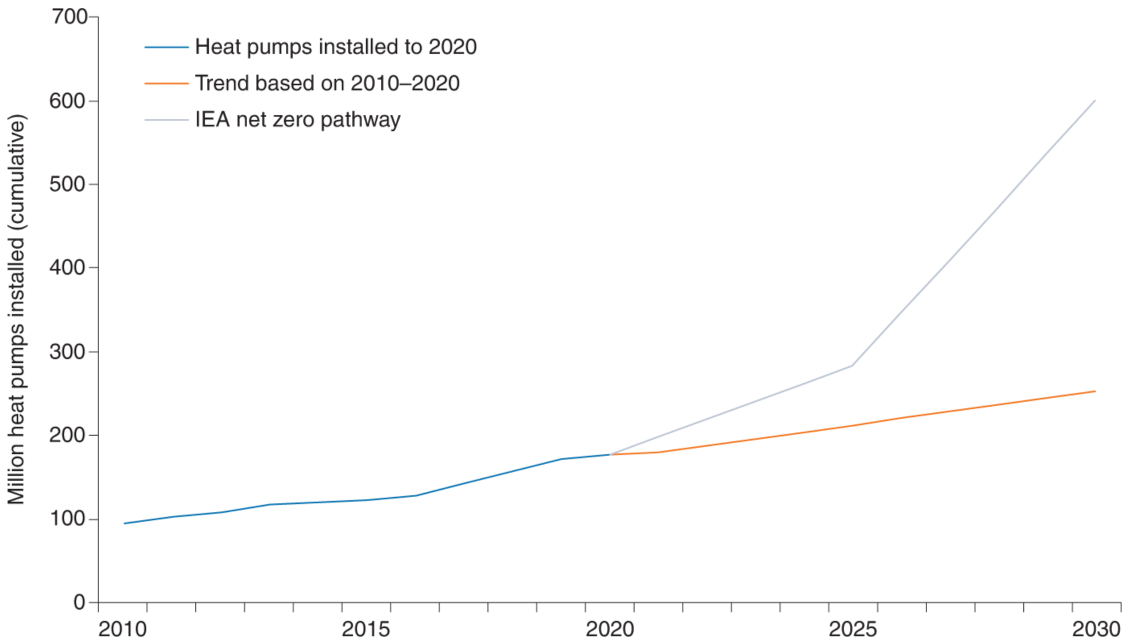

Figure 1: Heat pump installed and IEA net zero 2050 pathways (Rosenow et al., 2022)

Heat pumps, when integrated with renewable energy and thermal storage systems, emerge as a cornerstone for achieving cost-effective net zero emissions in Australian buildings and industry. For instance, coupling hot water heat pumps with rooftop solar photovoltaics transforms water heaters into thermal batteries, optimising on-site solar energy utilisation. Moreover, heat pumps excel in delivering low-temperature heat with minimal emissions. According to the International Energy Agency (IEA), solar-powered heat pumps outperform hydrogen-based boilers by a factor of five to six in energy efficiency when considering hydrogen production and transportation losses (IEA, 2021).

1.2 Aim

Acknowledging the significance of heat pump in supporting net zero emissions within Australian context, this report aims to investigate the following objectives:

- Solutions available of commercially available heat pumps in terms of temperature limitations, thermal performance characteristics, capacity, etc.
- Future plans for commercially available heat pumps over the next three years in terms of refrigerants, capacity, temperature performance.
- The current product acceptance processes under the white certificate schemes are voluntary and focused on estimates of energy savings. Should any other boxes be ticked for products entering the emerging heat pump market? How do we ensure quality products are installed safely, particularly through government funded interventions? What is the roadmap to address these? Is this roadmap different for C&I sectors and small- and large-scale applications within them?

2 Industrial heat pumps

2.1 Application and services

Heat pumps have versatile applications across sectors, including residential, commercial and industrial settings. These applications encompass sanitary hot water, space heating and cooling, pool heating, refrigeration, process water and product heating, process air heating and mechanical vapor recompression (MVR) in alumina.

Residential heat pump deployment offers the most immediate energy savings due to relatively low barriers to entry compared to commercial and industrial applications. While supply chains and skilled professionals for residential heat pump water heaters may be underdeveloped, targeted industry and government efforts can address these challenges.

Space heating and cooling in large commercial buildings is used in nearly 100% of the market. However, heating in large commercial buildings with centralised plant rooms remains uncommon. Commercial-sized heat pumps (exceeding 50 kW) constitute a small portion of the international heat pump market.

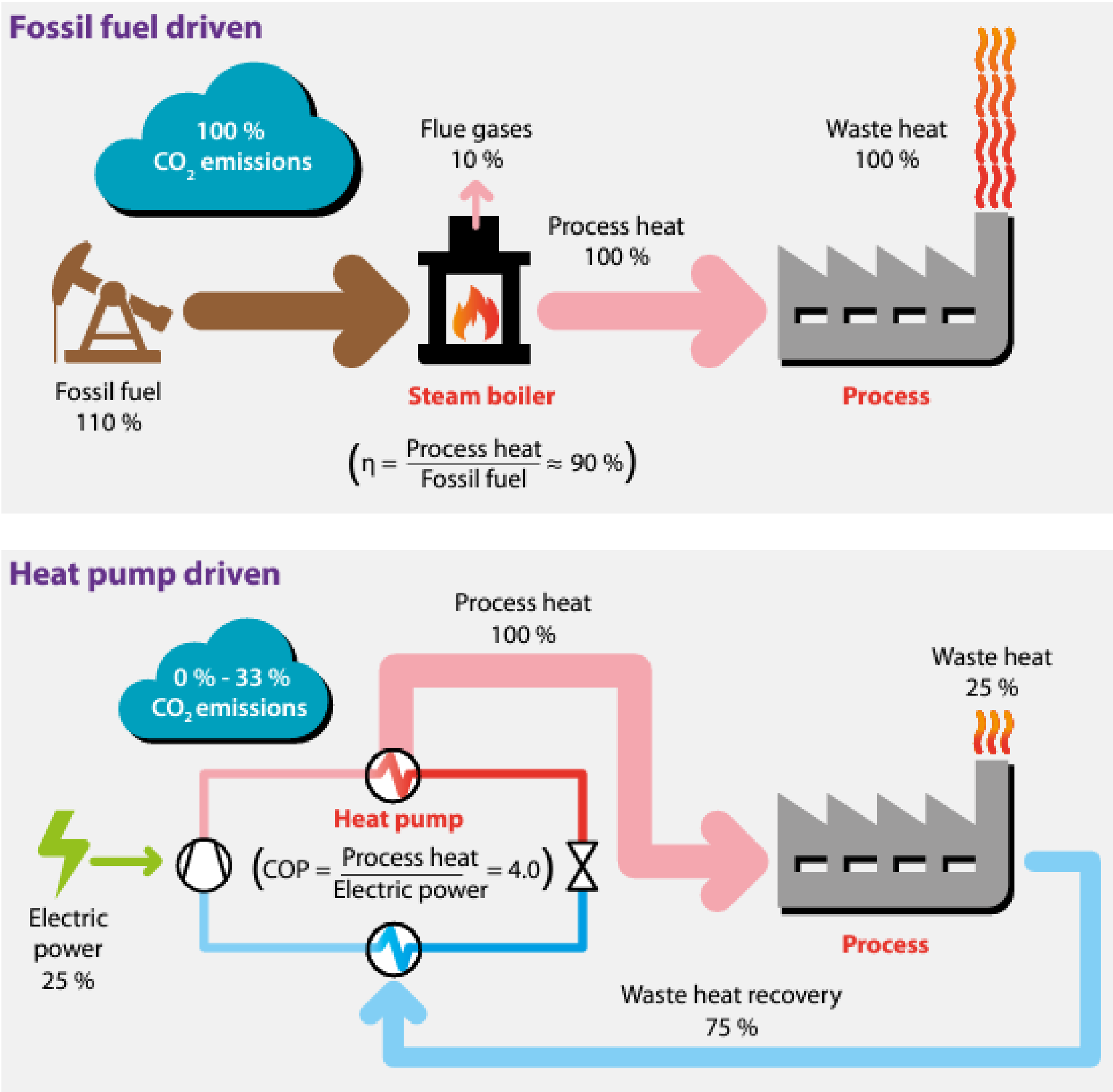

Figure 2: Comparison of fossil fuel driven, and heat pump driven industrial process schemes (Source: Boer et al., 2020)

Among the sectors analysed, industrial processes – particularly manufacturing and food processing – present significant opportunities for energy and emissions savings through heat pump adoption. Manufacturing accounts for 20% of Australia's total final energy consumption, contributing to 26% of the country's emissions. However, due to the complex nature of industrial applications, deployment estimates are subject to greater uncertainties and barriers.

Heat pumps can also be utilised in sectors such as agriculture, water and waste and transport.

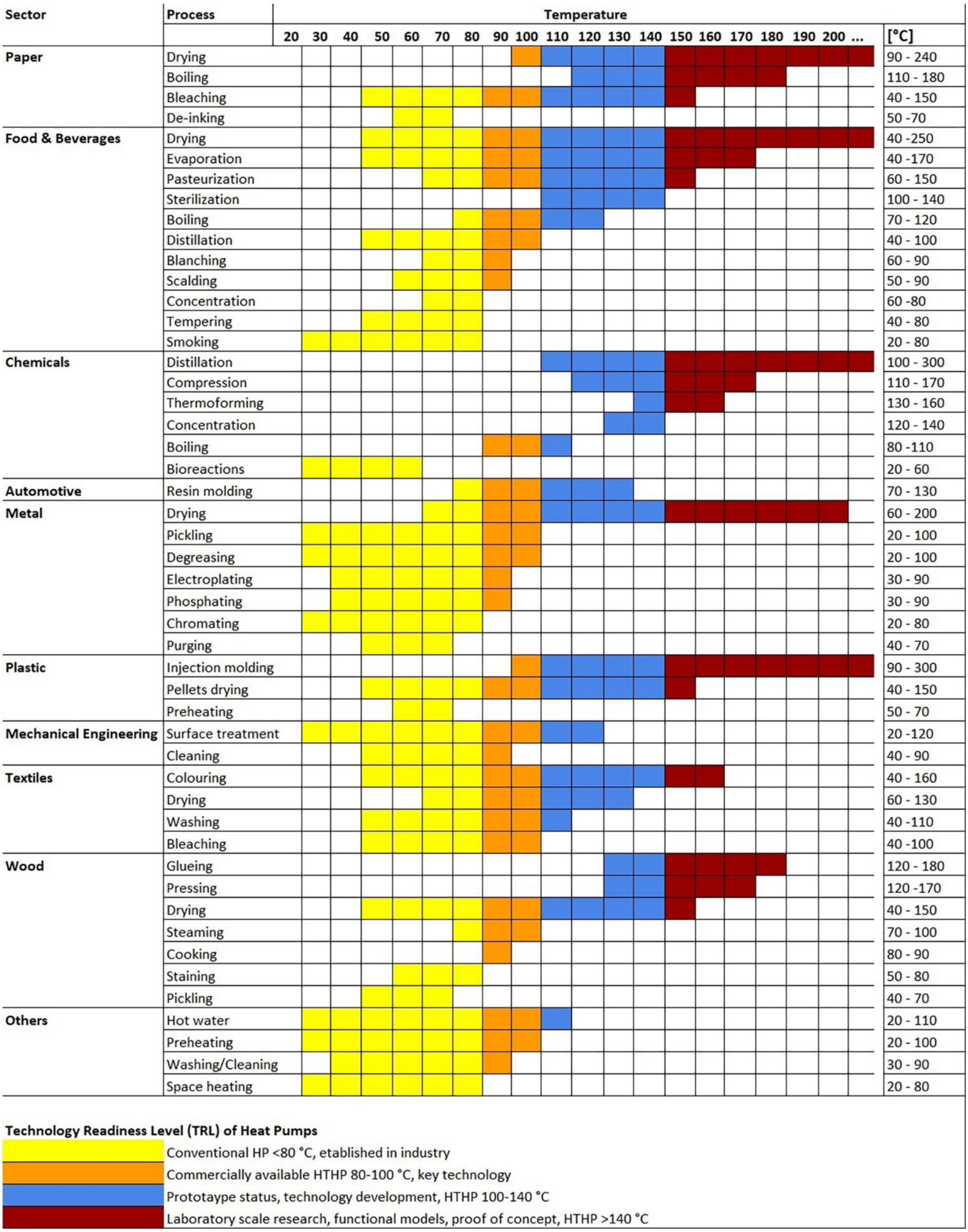

Figure 3: Process heating application at industries suitable for heat pumps (Source: Maruf et al. 2022)

3 State of the heat pump market

3.1 International market

Heat pumps are widely adopted in residential and small commercial buildings globally. Historically, fuel scarcity has been a primary catalyst for heat pump adoption. Countries such as Sweden, Switzerland and Finland, all leading European heat pump markets, have limited or no access to gas and access to cheap electricity from hydro or nuclear. While several European nations have taken the lead, others are rapidly catching up, motivated by emissions reduction goals. In Japan, carbon dioxide-based heat pump water heaters have gained significant traction, with nearly 500,000 units sold in 2018. Government policies, including installer training, performance standards and financial incentives, have been instrumental in driving heat pump adoption in successful countries.

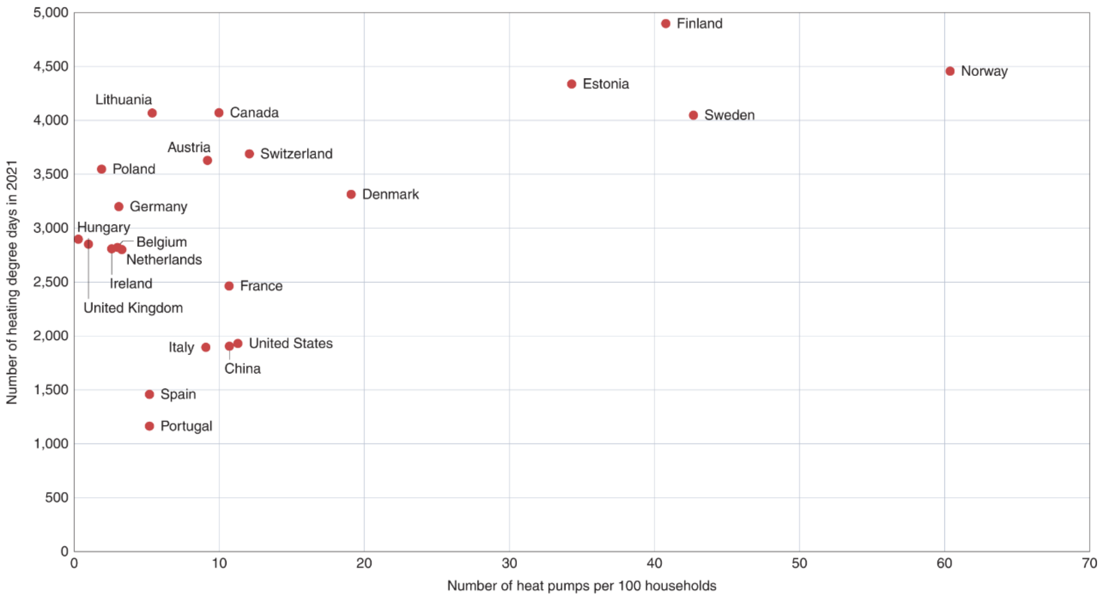

Figure 4: Heat pump penetration and number of heating degree days in selected countries (Source: Rosenow et al., 2022)

The US Department of Energy's Initiative for Better Energy, Emissions, and Equity seeks to promote clean heating and cooling systems, including heat pumps. A nationwide Advanced Water Heating Initiative aims to increase the market adoption of high-efficiency, grid-connected heat pump water heaters in residential and commercial buildings. Similarly, the United Kingdom (UK) Government launched the Renewable Heat Incentive (RHI) scheme in 2014 to incentivise renewable heating systems, including heat pumps, biomass boilers and solar thermal water heaters. Despite facing significant upfront costs, the scheme had limited success. To accelerate heat pump adoption, the UK Government announced plans in 2020 to install 600,000 heat pumps annually by 2028 and subsequently introduced grants of up to £5,000 to support heat pump adoption as part of its 2050 building decarbonisation plan.

Recognising the pivotal role of heat pumps in decarbonisation, international policymakers are taking action. Efforts focus on rapidly deploying mature technologies and accelerating nascent technologies through research and development. Europe, North America and Asia are leading in policy development and technological advancements with initiatives such as installer training, renewable heat incentives, heat pump-friendly building codes and gas-fired heating replacement programs.

3.2 Australian market

The technological and commercial maturity of heat pump technology varies across different applications and sectors within Australia. *Figure 5* shows estimates of the adoption of heat pump technologies in Australia along Rogers diffusion curve.

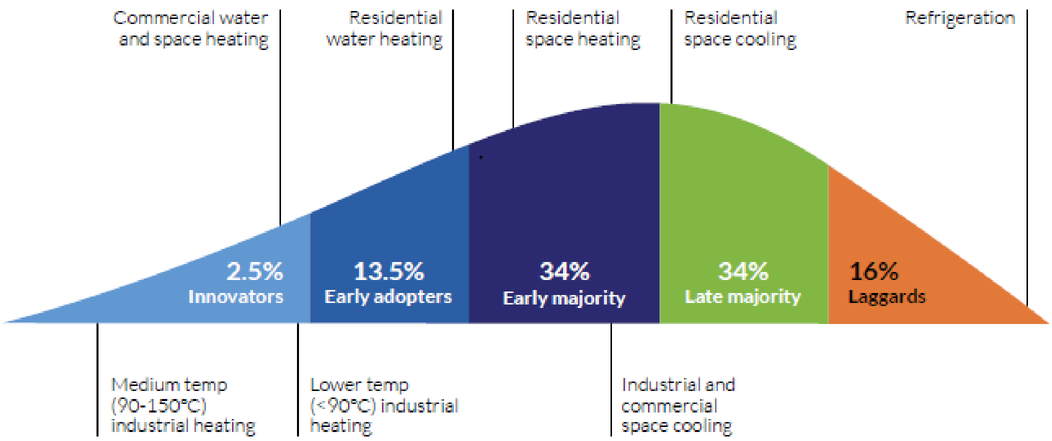

Figure 5: Estimation of heat pump technologies adoption within Australia (Source: EEC & A2EP, 2023)

In Australia where the climate is considerably varied and where there are four seasons across most of the country, heat pumps are generally used in both residential and commercial settings, serving a variety of purposes including air conditioning, potable water cooling, space heating and domestic hot water production. In Australia, heat pump water heaters currently account for approximately 3% of water heating systems. Table 1 presents a few recently completed heat pump projects within Australia.

Table 1: Examples of recently completed heat pump projects in Australia – not exhaustive (Source: Evoheat, 2024; Stiebel Eltron, 2024; Automatic Heating, 2024)

Company	Location
Automatic Heating	Eynesbury Recreation Reserve, Victoria
Automatic Heating	Yarra's Edge Tower 1
Evoheat	Auburn Ruth Everuss Aquatic Centre | Cumberland City Council, NSW
Evoheat	Dreamworld: White Water World | Gold Coast, QLD
Evoheat	George Town Swimming Pool | George Town, TAS
Evoheat	Newman College | Churchlands, WA
Evoheat	Wentworthville Aquatic Centre | Wentworthville, NSW
STIEBEL ELTRON	380 St Kilda Rd, Victoria
STIEBEL ELTRON	Brisbane Lions
STIEBEL ELTRON	Monash University, Victoria
STIEBEL ELTRON	Morris Property Group, Queensland

Nonetheless, residential heat pumps exhibit the highest commercial maturity, though adoption rates vary by application. Mature product ecosystems use established supply chains and a skilled workforce supports the widespread deployment in areas such as space heating and cooling. In contrast, commercial heat pumps, while technologically mature, face lower commercial maturity due to skill gaps in design, integration and deployment. To achieve economies of scale, development of these capabilities is essential in Australian context.

4 Latest technical development

4.1 Advancement in in high temperature heat pumps

There are recent advances in the high temperature heat pumps. For instance, a standard heat pump cycle with a sub-cooler can achieve a high coefficient of performance (COP) for low-temperature applications. Sub-coolers, which use an external heat sink, reduce throttling losses and refrigerant flow rate, maximising the COP. However, the maximum temperature lift is limited by the pressure ratio of a single compression stage. While standard cycles typically achieve temperature lifts around 30 °C, advanced cycles can reach up to 110 °C. For heat sink temperatures below 100 °C, reported COPs range from 1.8 to 6.6. Above 100 °C, COPs are generally lower, between 1.7 and 2.8. Multiple parallel standard cycles can significantly improve COP for applications with large temperature gradients with an overall COP of 4.22 with multiple heating stages. Table 2 represents a selection of recent advances in the high temperature heat pumps area.

Table 2: Recent advances in the heat pump area (Source: Adamson et al., 2022

Code	Technology area	Cycle	T_{sink} (out)/T_{cond} (°C)	T_{source} (in)/ T_{evap} (°C	Refrigerant	COP	Experimental (E) or simulation (S)
S1-1a	Standard cycle with and without external sub-cooler	Subcritical, single stage	140/-	60-100/-	R1234ze (Z)	1.7–3.2	S
S1-1b	Standard cycle with and without external sub-cooler	Subcritical, single stage with separator	-/110-150	-/80	R718	4.8-1.9	E
S1-1b	Standard cycle with and without external sub-cooler	Subcritical, single stage with separator	-/110–150	-/85	R718	6.1-2	E
T1-1	Transcritical, single stage (Standard transcritical vapour	Subcritical, single stage with separator	200/-	30-80/-	R514A	2.9-3.3	S

	compression cycle)						
SE-2	Internal heat exchanger and internal economiser cycles.	Subcritical, two compression stages with closed economiser and IHX	130/-	30-90/-	R245fa	5-2.1	S
SI-1	Intercooling, parallel compression and multi-stage compression cycles	Subcritical, two compression stages with open economiser/intercooler	140/	40-100/-	R1234ze (Z)	1.8-3.8	S
SS-2	Cascade cycles	Cascade with subcritical, single stage with IHX (top) and subcritical, single stage with IHX (bottom)	130/-	30-90/-	R245fa	4.9-2.5	S
SM-1	Multi-temperature cycle	Subcritical, two condenser stages with IHX	130/-	30-90/-	R245fa	6.7-1.2	S

4.2 Refrigerants

The refrigerant market has undergone significant transformation over the past four decades due to environmental concerns. The Montreal Protocol (1987) initiated the phase-out of chlorofluorocarbons (CFCs), such as like R11 and R12, which were severely damaging the ozone layer. Historically, each transition to new refrigerants has spurred innovation, expanding the technology's efficiency and applications. The current phase-down of hydrofluorcarbons (HFCs) and the pursuit of low-global-warming-potential refrigerants have propelled CO_2 to the forefront as a major new option. Table 3 presents different types of working fluids with the attributes.

Table 3: Working fluids with different attributes ranked by GWP (Source: Andersen et al., 2024)

Fluid	Fluid no.	Type	GWP	Normal boiling point [°C]	Critical temperature [°C]	Critical pressure [bar]	Safety class
Ammonia	R-717	Inorganic	-	−33.3	132.3	113.3	B2L
Water	R-718	Inorganic	-	100.0	373.9	220.6	A1
Isobutane	R-600a	HC	-	−11.7	134.7	36.3	A3
Pentane	R-601	HC	-	36.1	196.6	33.7	A3
Isopentane	R-601a	HC	-	27.8	187.2	33.8	A3
	R-1224yd.(Z)	HFO	0.88	14.6	155.5	33.4	A1
Dimethyl ether (DME)	R-E170	Ether	1	−24.8	127.2	53.4	A3
CO_2	R-744	Inorganic	1	-	31.0	73.8	A1
	R-1336mzz(Z)	HFO	2	33.5	171.4	29.0	A1
Ethane	R-170	HC	2.9	−88.6	32.2	48.7	A3
Propane	R-290	HC	3	−42.1	96.7	42.5	A3
Butane	R-600	HC	3	−0.5	152.0	38.0	A3
Hexane	R-602	HC	3.1	68.7	234.7	30.4	A3
	R-1234ze(E)	HFO	6	−19.0	109.4	36.3	A2L
	R-1234ze(Z)	HFO	6	9.7	150.1	35.3	A2L
	R-1233zd(E)	HFO	77	18.3	166.5	36.2	A1

4.3 Mechanical vapour recompression

Mechanical vapour recompression (MVR) is a specialised heat pump technology traditionally used in low-temperature evaporation processes requiring a minimal temperature increase (less than 15 °C) and typically delivering coefficient of performance (COP) values exceeding 10. This technology is commonly applied below 100 °C but can generate heat up to 250 °C.

MVR technology has broad applicability across numerous evaporation processes in manufacturing industries, including sugar refining, fruit juice concentration, chlor-alkali, meat rendering, malt extract, glucose, fructose, starch and ethanol distillation. Furthermore, MVR technology can be utilised in the digestion and evaporation stages of alumina processing. In fact, MVR technology used for evaporation processes is well developed and proven in many applications and therefore it is estimated to have a technology readiness level (TRL) greater than seven. Nonetheless, MVR technology at the higher temperatures required for alumina digestion – approximately 150 °C to 160 °C for west coast refineries and 230 °C to 250 °C for refineries on the east coast – has not yet been applied at scale but is considered feasible by some technology suppliers.

4.4 CO_2 heat pumps

Carbon dioxide (CO_2) heat pumps are gaining widespread availability in various configurations and from numerous suppliers. These systems offer a higher COP than HFC heat pumps in applications requiring significant temperature differentials between the water inlet and outlet. CO_2 heat pumps can operate at temperatures up to 90 °C while maintaining a high COP.

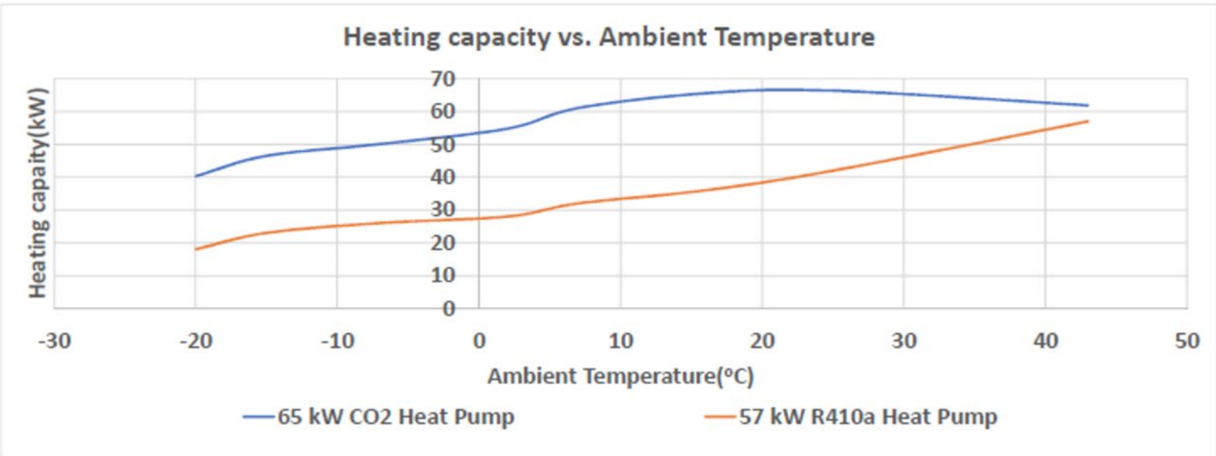

Figure 6: Heating capacity of CO_2 heat pump as a function of ambient temperature (Source: Automatic Heating, 2024)

4.5 Two-speed compressors

While traditional compressors run at full capacity, two-speed compressors enable heat pumps to adjust their output to match the specific heating or cooling demand, reducing energy consumption and wear on the compressor. These compressors are particularly effective when paired with zone control systems, commonly found in larger homes and commercial buildings. Zone control systems utilise automatic dampers to regulate airflow, allowing heat pumps to maintain different temperatures in individual rooms, further optimising energy efficiency.

4.6 Dual-fuel or hybrid systems

Although most heat pumps use electric resistance heaters as a backup for cold weather, heat pumps can also be equipped in combination with a gas furnace, sometimes referred to as a dual-fuel or hybrid system, to supplement the heat pump. This helps solve the problem of the heat pump operating less efficiently at low temperatures and reduces its use of electricity.

There are few heat pump manufacturers that incorporate both types of heat in one box, so these configurations are often two smaller, side-by-side, standard systems sharing the same ductwork. In comparison with a combustion fuel-fired furnace or standard heat pump alone, this type of system can also be more economical. Actual energy savings depend on the relative costs of the combustion fuel relative to electricity.

4.7 Scroll compressor

Another advance in heat pump technology is the scroll compressor, which consists of two spiral-shaped scrolls. One remains stationary, while the other orbits around it, compressing the refrigerant by forcing it into increasingly smaller areas. Compared to the typical piston compressors, scroll compressors have a longer operating life and are quieter. According to some reports, heat pumps with scroll compressors provide 10 °F to 15 °F (5.6 °C to 8.3 °C) warmer air when in the heating mode, compared to existing heat pumps with piston compressors (*Adamson et al., 2022*).

4.8 Other technologies

Some models of heat pumps are equipped with variable-speed or dual-speed motors on their indoor fans (blowers), outdoor fans, or both. The variable-speed controls for these fans attempt to keep the air moving at a comfortable velocity, minimising cool drafts and maximising electrical savings. It also minimises the noise from the blower running at full speed.

Also, some high-efficiency heat pumps are equipped with a desuperheater, which recovers waste heat from the heat pump's cooling mode and uses it to heat water. A desuperheater-equipped heat pump can heat water two to three times more efficiently than an ordinary electric water heater.

5 Key take-aways from Australian heat pump market players

A set of interviews with key operators in the C&I heat pumps Australian market has been presented and discussed, providing insights around current products and solutions offered, refrigerants, as well as relevant considerations around heat pumps system design and incentive schemes, with the aim of gathering an Australian market perspective. Interviews covered the following areas:

- Product ranges
- Future products
- Refrigerants
- System design challenges
- White certificate schemes.

As shown by the Table in Appendix B, the selection of companies, whilst it does not include all operators in the Australian C&I market, it provided coverage of the broad spectrum of solutions, in terms of type of heat pumps, different product sizes, as well as different type of refrigerants (see Appendix B). Key take-aways and main messages from the extensive interviews with market players have been summarised in the following sub-sections.

5.1 Product temperature ranges

The heat pump market is characterised by a wide array of technological options, with companies tailoring unit capacities and refrigerant choices to meet specific application needs. While synthetic refrigerants like R32, R410A and R134a dominate the lower-capacity market (10 kW to 2,000 kW), natural refrigerants such as R744 (CO_2) and R290 (propane) are emerging as sustainable alternatives, especially in high-capacity and environmentally sensitive applications.

For instance, air-source heat pumps, which can operate across a broad temperature range from 25 °C to 43 °C, are suited to variable climates and diverse applications. However, liquid-to-water heat pumps, with their narrower operational range of -5 °C to 20 °C, offer more specialised solutions, particularly for regions where ground or water sources can be leveraged for consistent heating and cooling. What sets companies apart is their strategic approach to technology deployment. Leading manufacturers are now offering R290 air-to-water heat pumps capable of delivering 70 °C to 75 °C hot water without the need for cascade systems—a significant leap in efficiency and capability. This advancement highlights the industry's commitment to pushing the boundaries of heat pump performance by integrating cutting-edge compressor technologies, including scroll, screw, centrifugal and magnetic bearing compressors, in both cooling and heating systems.

5.2 Future products

As companies innovate to meet growing environmental and efficiency demands, overcoming the traditional limitations of heating systems has become a key focus. A major development lies in widening the temperature range of heating hot water loops by 15 °C to 20 °C. This breakthrough enables heat pumps to be integrated into retrofit projects without requiring extensive changes to pipework, provided the existing infrastructure is suitable for reuse.

At the same time, companies are experimenting with new refrigerant blends, such as R1234ze, designed to work with cascade configurations for high-temperature steam generation, which are particularly relevant for industrial applications. Alongside this, the development of low embodied carbon refrigerants, such as ammonia, ammonia-water blends and hydrocarbons, is pushing the industry toward more sustainable solutions.

In parallel, new products, such as oil-free magnetic bearing centrifugal heat pump boosters, are being introduced to the market, compatible with low-GWP refrigerants. However, the shift to natural refrigerants is becoming an industry-wide trend. Most companies now recognise that most of their future products will rely on natural refrigerants, particularly hydrocarbons like R290.

5.3 Refrigerants

While many companies have increasingly turned to natural refrigerants like R290, and in some cases R744, their adoption often depends on application suitability. However, water as a refrigerant for heating applications and mechanical vapor recompression is also under exploration, reflecting the industry's commitment to advancing more sustainable solutions.

Simultaneously, companies continue to utilise synthetic refrigerants like R1233zd and R514 in low-pressure centrifugal compressors, striking a balance between environmental considerations and performance needs. Moreover, R454B has started to capture some market attention, providing another alternative for industries.

Synthetic refrigerants, such as R1234yf and R454C, are expected to face growing restrictions due to their environmental toxicity, with frameworks like the European Union's F-Gas regulation pushing for their gradual phase-out. One company's recent establishment of a dedicated R290 product supply line is a clear indication of this shift. This development is particularly interesting in light of the complexities of refrigerant supply and the need for sustainable options.

5.4 System design challenges

When it comes to system design, companies emphasise the need to think beyond traditional frameworks. They argue that a significant gap in understanding exists, particularly among engineers who may lack in-depth knowledge of equipment and suppliers who are under-resourced to offer meaningful design support. This disconnect underscores the importance of educating stakeholders on critical concepts such as thermal and buffer storage, which are often overlooked.

Few of the companies advocate for the adoption of thermal storage systems, promoting the 'thermal battery' concept. However, they insist that a more holistic approach is necessary, one that integrates co-generation principles. For instance, liquid-to-water heat pumps utilising higher source temperatures from on-site chiller lines can enhance both heating and cooling applications, making system design more efficient and versatile. Moreover, they emphasise that energy management operations must be dynamic, relying on real-time forecasts of energy availability, renewable energy contributions, spot-pricing control of electrical tariffs and additional buffering through thermal storage to optimise system performance.

Another critical point companies raise is the impact of proper installation on energy efficiency. Poor installations can result in significant energy losses, eroding the system's potential benefits, with additional operating costs and maintenance efforts. To address this, some companies have shifted to multi-pipe systems that incorporate energy storage, offering a more integrated and often cost-effective solution. These companies employ cascade systems capable of producing water at 80 °C to 90 °C, suited for both new builds and retrofits, arguing that such innovations are crucial for optimising both economic and environmental outcomes in heating and cooling projects.

5.5 White certificate schemes

The research also aimed to provide several insights around the regulatory frameworks to support the deployment of heat pumps in the commercial and industrial markets. In this regard, considering that the current product acceptance processes under the white certificate schemes is voluntary (and is focused on estimates of energy savings) additional elements should be investigated to promote a widespread adoption of heat pumps.

When looking at which additional considerations should be made for products entering the emerging heat pump market, respondents highlighted the need for the system configuration to remain flexible, while placing greater emphasis on precision regarding the product and supplier selection.

The existing registration system primarily focuses on registering products with a specific water volume, largely due to the widespread adoption of the TRANSYS modelling approach. While this methodology is suitable for smaller systems (e.g., domestic hot water heaters), it seems less effective for large-scale systems where heat pumps are designed to operate flexibly across a wide range of potential scenarios. These scenarios involve varying system designs, site configurations, water volumes and thermal heating loads, which complicates testing. Most testing is conducted on water loops of fixed size yet heat pump performance can vary significantly depending on ambient conditions, particularly water-side hydraulics.

Furthermore, products should be sourced from reputable suppliers with well-established supply chains. This includes adherence to modern slavery statements, possession of relevant certifications for components such as heat exchangers and having a track record of supplying quality, certified and reputable products. Additionally, suppliers should possess localised skill sets to ensure proper installation, maintenance and support.

There is often a tendency to focus on products eligible for rebates, leading customers to prioritise pricing without fully considering the long-term reliability of the equipment. This can result in the emergence of ‘pop-up’ suppliers who provide products without long-term support, which may create significant problems when service or repairs are needed. In such cases, critical components or product knowledge may no longer be available, leading to increased costs and system downtime.

To achieve higher product standards, a more thorough audit of the supplier′s history and qualifications should be conducted before any product registration. This would include verifying the supplier′s ability to honour warranty obligations. Additionally, the Victorian Energy Upgrades (VEU) program has been observed to have minimal internal reference points for quality assurance, with efficiency being the primary metric. While there is room for improvement in this area, determining the right criteria for assessing quality remains challenging. Higher-priced suppliers often criticise the quality of cheaper products, but when pressed, they struggle to provide solutions for addressing quality concerns within the program. Quality, in this context, refers to the unit′s construction, materials (e.g., rust resistance) and selection of major components.

Additionally, ensuring the safe installation of quality products, particularly through government-funded interventions, is critical. While audits can be effective, their impact often depends on the auditor’s approach. In some cases, audits can magnify minor issues that, in the context of the overall project, do not pose significant risks. For instance, small issues may trigger unnecessary actions, such as a complete 'pull-out and restart', even though these may not affect the safe operation or reliability of the system. This could occur when an auditor is particularly focused on minute details, pushing for compliance in areas that may not be universally understood.

In the recent times, clients involved in fuel switching projects are becoming increasingly cautious and are reassessing their commitment to further upgrades, as they are uncertain about the ability of project-based activities (PBAs) to consistently deliver the promised incentives. In response, energy service companies (ESCOs) appear to be hiring more measurement and verification (M&V) personnel, suggesting a belief that the solution lies in adding more staff rather than optimising the auditing and approval process to enhance efficiency. Meanwhile, many accredited persons are carefully evaluating small- and medium-sized enterprises and fuel switching projects, considering them to be high-risk and administratively demanding. As a result, the accuracy of M&V, which is primarily deemed, has sparked further discussions. This shift has led to heat pump projects exploring Activity 44 as an alternative to PBAs, due to the need for a more streamlined approach and the relatively limited number of Victorian energy efficiency certificates (VEECs) that can be generated. Simultaneously, it is observed that the ownership of the 'accreditation' for the white certificate schemes is unclear to industry members, with uncertainty about whether it falls to the supplier, the installer, or another party. Providing clarity on this matter would help ensure that all roles in the process are well-defined and easy to follow.

Additionally, the distinction between code compliance and safe heat pump installation needs to be clarified. Installers may not be fully familiar with every code detail, but they can generally ensure safe installations. Auditing to high standards is difficult when codes aren't easily accessible or top-of-mind, making training and education essential. In this regard, the heat pump testing process could be redefined to focus on its flexibility in various conditions, rather than tying it to a specific configuration. Testing should expose the heat pump to different ambient conditions and water flow rates to demonstrate its ability to adapt, especially in space heating applications where load fluctuations occur, and system response time is critical.

A potential roadmap to address such concerns could involve developing a high-level tool to estimate certificate values for around 60% of facility types, simplifying the process. This tool would allow users to input facility details, select a registered product, and receive an estimated saving, which would then be converted into a certificate value. However, the scaling process must be adaptable for each site, as some facilities can be modelled with higher accuracy and require less user input, while others may need more detailed analysis.

Facility templates could cover categories such as manufacturing, hospitals, hotels and offices, each with varying levels of complexity. For instance, energy usage in offices is more predictable due to factors like occupancy, while manufacturing requires a more granular approach due to its fluctuating energy needs. While this tool has the potential to streamline the process, a key concern is the risk of 'fly-by-night' suppliers exploiting the system. Simplifying certificate acquisition could allow some suppliers to secure certificates without delivering the necessary energy savings.

Additionally, refocusing the purpose of the M&V plan is essential. In fact, implementing metering for larger C&I systems wherever possible is crucial. Additional rebates for quality metering – capturing variables like ambient temperature, occupancy, or production load – would be beneficial. Internet of Things (IoT) metering at scale could also prove valuable, with further guidance from relevant industry bodies.

Another key aspect is redefining the testing process. The current challenge of testing larger units in Australia, coupled with specific configuration constraints, can overwhelm suppliers. To address this, a local test lab could be established to simulate a variety of conditions heat pumps might encounter in different applications. Meanwhile, the product registration process should be streamlined while ensuring adequate checks for local knowledge, reference sites and the supplier's business practices.

Supporting the installation process with clear guidelines and proper training is also critical. Installers should receive ongoing education to stay updated on installation protocols and safety measures, ensuring they can install heat pumps according to best practices. Regular audits and inspections should be conducted to ensure compliance without imposing overly stringent requirements that may hinder progress.

The ownership of the white certificate scheme accreditation also needs clarification. It seems illogical for suppliers, who already put in significant work to get registered, to not also be responsible for measuring and verifying installations, especially for sample sizes. Although some companies manage this, larger systems over 800 kW present challenges.

On a separate note, PBAs could add value, currently representing approximately 6% of VEEC volume. While more than 70% of projects are straightforward and largely similar, such as solar PV and HVAC-R projects in supermarkets, there is room for improvement. Adjusting the role of certifiers is essential, adopting a balanced evaluation approach based on materiality and 'resonance accuracy'. Certifiers should avoid overly detailed nit-picking and instead focus on evaluating project claims based on the overall materiality of any rule or method.

Finally, respondents highlighted the need to tailor the roadmap according to the specific needs of the commercial vs industrial sectors, as well as across small- and large-scale applications. For instance, larger scale industrial applications require more granular and detailed processes to handle the complexity involved in upfront qualifications and the subsequent M&V procedures. These systems are inherently more complicated due to the varying operational processes and product types within the same factory, making it difficult to standardise and model energy outcomes. This complexity demands a more customised approach for defining and linking key metrics to accurately predict energy consumption and savings.

In contrast, commercial applications, which typically have fewer variables influencing energy loads (such as predictable factors like occupancy) are relatively easier to model and assess. Therefore, the qualification and M&V processes can be more straightforward.

For large-scale industrial products, additional challenges emerge in testing. Due to the high costs of specialised test labs – such as those needed for ammonia-based refrigerants – conducting local tests in Australia could be prohibitive. This situation calls for alternative solutions, such as independent witnessing of tests at global test labs or operational sites or potentially establishing a state-of-the-art test lab in Australia that adheres to the highest international standards.

Despite the differences in roadmap design for various applications, a more cost-effective and efficient solution could involve aligning the testing process with internationally recognised performance frameworks, such as the Air-Conditioning, Heating and Refrigeration Institute (AHRI) and Eurovent. These frameworks, commonly used in Australia for chillers and air-handling units, offer independent certification for heat pump performance. By integrating these standards, the need for redundant testing can be reduced, ensuring that only high-quality, verifiable products are registered. This alignment would not only streamline the testing process but also enhance the reliability of certified products, benefiting both suppliers and consumers alike.

References

Andersen, M. P., Zühlsdorf, B., Markussen, W. B., Jensen, J. K., & Elmegaard, B. (2024). Selection of working fluids and heat pump cycles at high temperatures: Creating a concise technology portfolio. *Applied Energy*, *376*, 124312. https://doi.org/10.1016/J.APENERGY.2024.124312

Adamson, K. M., Walmsley, T. G., Carson, J. K., Chen, Q., Schlosser, F., Kong, L., & Cleland, D. J. (2022). High-temperature and transcritical heat pump cycles and advancements: A review. In *Renewable and Sustainable Energy Reviews*. https://doi.org/10.1016/j.rser.2022.112798

Automatic Heating (2024), Automatic Heating Global Pty Limited, 2024, Australia.

Boer, R., Marina, A., Zühlsdorf, B., Arpagaus, C., Bantle, M., Wilk, V., Elmegaard, B., Corberán, J., Benson, J. (2020). Strengthening Industrial Heat Pump Innovation Decarbonizing Industrial Heat, Danish Technical Institute, Denmark.

Eltron, Stiebel. (2024). *Project Portfolio*. Retrieved from https://www.stiebel-eltron.com.au/projects

EvoHeat. (2024). Retrieved from Award-Winning Pool Heating & Cooling Solutions: https://evoheat.com.au/

Energy Efficiency Council and Australian Alliance for Energy Productivity 2023, Harnessing heat pumps for net zero, Energy Efficiency Council, Melbourne.

Heat Pump Centre (HPC) 2024, High Temperature Heat Pumps, Task 1 – Technologies, Task Report, Sweden.

International Energy Agency (IEA) 2022, *The Future of Heat Pumps, World Energy Outlook Special Report 2022*, IEA, Paris, France.

International Energy Agency (IEA) 2021, *Global hydrogen review 2021*, IEA, Paris, France.

Maruf, M. N. I., Morales-España, G., Sijm, J., Helistö, N., & Kiviluoma, J. (2022). Classification, potential role, and modeling of power-to-heat and thermal energy storage in energy systems: A review. *Sustainable Energy Technologies and Assessments*. https://doi.org/10.1016/j.seta.2022.102553

Rosenow, J., Gibb, D., Nowak, T., & Lowes, R. (2022). Heating up the global heat pump market. Nature Energy, 7(10), 901–904. https://doi.org/10.1038/s41560-022-01104-8

Appendix A: C&I Heat Pump suppliers in Australia.

C&I Heat Pump Supplier (alphabetical order)	Website
Australian Hydronics	https://australianhydronics.com.au
Automatic Heating	https://automaticheating.com.au
Daikin	https://www.daikin.com.au
EcoAlliance	https://ecoalliance.com.au
Ecotherm	https://www.ecotherm.com.au
Energy Smart Water	https://esw.net.au
EvoHeat	https://evoheat.com.au
GEA	https://www.gea.com/en/products/heat-pumps/
Geoclima	https://www.geoclima.com/pro_cat/australia/
Geothermal Heating and Cooling	https://geothermalaustralia.com.au
Glaciem	https://glaciemcooling.com
Highlands GeoExchange	https://www.highlandsgeo.com.au
Howden	https://www.chartindustries.com/Businesses-Brands/Howden
HydroHeat	https://www.hydroheat.com.au
Johnson Controls	https://www.johnsoncontrols.com.au
Mayekawa	https://www.mayekawa.com.au
Mitsubishi Electric	https://au.mitsubishielectric.com/en/index.html
Mitsubishi Heavy	https://www.mhiaa.com.au
Piller	https://www.piller.de/industrial-heat-pump/
Reclaim Energy	https://reclaimenergy.com.au
Rheem	https://www.rheem.com.au/rheem/
Rinnai	https://www.rinnai.com.au
Smardt	https://smardt.com
Steibel Eltron	https://www.stiebel-eltron.com.au
Toyesi	https://toyesi.com.au
Trane	https://trane.eu/au/

Appendix B: Details of selected companies who provided insights on their C&I heat pumps in Australia.

		Automatic Heating	Geoclima	Johnson Controls	Steibel Eltron	Trane
Sector focus	Residential	✓			✓	
	Commercial	✓	✓	✓	✓	✓
	Industrial		✓	✓		
Heat source	Air	✓	✓		✓	✓
	Water		✓	✓	✓	✓
Compressor types	Scroll		✓		✓	
	Screw	✓	✓	✓		✓
	Reciprocating	✓	✓	✓		
Refrigerants	HFC		✓			
	HFO		✓		✓	✓
	Ammonia			✓		
	Propane	✓	✓		✓	✓
	CO_2	✓				
Size	<30 kW	✓	✓		✓	✓
	30-100 kW	✓	✓	✓	✓	✓
	100-500 kW	✓	✓	✓		✓
	>500 kW		✓	✓		✓

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