Harnessing heat pumps for net zero

The role of heat pumps in saving energy and cutting emissions

February 2023

energy efficiency COUNCIL

AUSTRALIAN ALLIANCE FOR ENERGY PRODUCTIVITY

This report has been prepared by the Australian Alliance for Energy Productivity (A2EP) and Energy Efficiency Council (EEC) for the Australian Government Department of Climate Change, Energy, the Environment and Water (DCCEEW).

Citation:

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

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About the Australian Alliance for Energy Productivity

The Australian Alliance for Energy Productivity (A2EP) is an independent, not-for-profit coalition of industry and research leaders helping Australian businesses pursue a more successful future by producing more with less energy.

We explore world's best practice, connect our stakeholders and advocate for change to help energy users improve productivity and profitability, grow enterprise and employment, facilitate circular economy solutions, and manage an orderly transition to decarbonisation. We believe that an emphasis on energy productivity from industry and government will deliver significant economic and environmental benefits, strengthen energy independence and increase global competitiveness.

Established in 2009, our work ranges across research, demonstration and communication. Our innovation program accelerates the uptake of technologies that have benefits for energy users, energy systems and the economy. We focus mainly on the manufacturing, agriculture and transport sectors as well as energy intensive commercial buildings.

Our recent projects have spanned a range of themes focussed on decarbonisation in practice, including industrial process heat, Industry 4.0 and digitisation, bioenergy, electrification and the transition from gas, on-farm energy productivity, flexible electricity demand and demand control.

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About the Energy Efficiency Council

The Energy Efficiency Council (EEC) is Australia's industry association for energy management, energy efficiency and demand response. The EEC is a not-for-profit membership association for businesses, universities, governments and NGOs.

Founded in 2009, the EEC's members are diverse, but are united by a common cause: building a sophisticated market for energy management products and services that delivers:

- Healthy, comfortable buildings;
- Productive, competitive businesses; and
- An affordable, reliable and sustainable energy system for Australia.

The EEC's job is to make Australia a global leader in smart energy management. To this end, the Council works with its members and partners to:

Drive ambitious government policy by advocating for smart energy management policies and programs that deliver for all Australians;

- Support business decision making and growth with trusted, impartial information on energy so that businesses have confidence making the right energy management investments; and
- Ensure quality with standards and professional development by supporting standards development and benchmarking for the sector, and training and professional development for professionals across Australia.

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Foreword

The heat pump is finally taking its turn in the spotlight, and not a moment too soon.

Australia has recently legislated an emissions reduction commitment – 43 per cent reduction on 2005 levels by 2030. This report finds that heat pumps can play a crucial role in this effort, driving down emissions, and improving energy affordability.

The opportunity for heat pumps, coupled with process optimisation and renewables, to help decarbonise key industrial subsectors is large; this report finds that emissions reductions of 391 Mt CO_2e in industrial processes are possible to 2050.[1] The evidence that electrification is the fastest, least-cost pathway to net zero in residential and commercial buildings is also very strong,[2] and this report finds that in Australia, heat pumps can achieve emissions reductions of 260 Mt CO_2e in residential buildings, and 96 Mt CO_2e in commercial buildings between 2020 and 2050. The combined emissions reduction potential in these sectors is equivalent to about one and a half years of Australia's total emissions.[3]

Indeed across all sectors examined, this report finds that heat pumps can achieve potential cumulative energy savings of up to 14,391 PJ to 2050, with the added benefit of reducing exposure to volatile global gas markets. Importantly, heat pumps can take advantage of Australia's decarbonising grid by using energy when renewable generation is plentiful, ensuring we electrify intelligently and only pay for the generation, network and storage infrastructure that we actually need.[4]

For the first time, this report gives us some sense of the size of the prize, but realising it will require sustained effort, with a focus on *policy* and *deployment*.

We are starting from a low base, with one exception: reverse cycle air conditioners are very common in Australian households. However, use of heat pumps for hot water, space heating and low temperature process heat is lagging other parts of the world. Further, deploying mature heat pump technologies now will mean we are well placed to adopt emerging technologies as they become available, including higher temperature applications in industry.

Time is of the essence – focusing on deploying heat pumps in the three sectors examined in this report by 2030 will help us quickly develop the skills and supply chains we need, maximise cumulative emissions reductions to 2050, and ensure heat pumps play their part in delivering a prosperous, net zero Australia.

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1 Emissions reductions based on AEMO 'step change' scenario in the 2020 Integrated System Plan.

2 Australian Sustainable Built Environment Council (ASBEC) 2022, *Unlocking the pathway: Why electrification is the key to net zero buildings*, ASBEC, Sydney.

3 Based on Australia's annual emissions 2021 at 488 Mt CO_2e.

4 International Energy Agency (IEA) 2022, *Heat pumps tracking report – September 2022*, IEA, Paris.

Acknowledgements

The Australian Alliance for Energy Productivity (A2EP) and the Energy Efficiency Council (EEC) gratefully acknowledge the many organisations and individuals that contributed to the development of this report.

In particular, we would like to highlight the support of the Australian Government Department of Climate Change, Energy, the Environment and Water (DCCEEW).

We would like to acknowledge the valuable contribution made by the following individuals who agreed to be interviewed for this report:

- Veerle Beelaerts, Head of Technology and Marine de Cornulier, Junior Policy Advisor, European Heating Industry Association;
- Troy Burgess, Applied Channel Manager, Mark Maclean, National Product Manager – Applied Solutions, Gaurav Malik, National Planning Manager and Asahi Takahiro, Heat Pump and Thermal Storage Technology Center of Japan, Daikin Industries Ltd.;
- Daniel Chadwick, General Manager – Major Projects and Dhruv Iyer, Accounts Team Leader, Australian Energy Foundation;
- Ben Cirulis, Strategic Delivery Manager, Residential Sustainability Projects Branch, NSW Department of Planning and Environment;
- Glenn Day, Director National Sales and Public Affairs, Peter Beamish, Account Manager, Tom Stephenson, National Sales Manager – Renewable Technologies and Rani Guarnieri, Technical Manager, Stiebel Eltron (Australia) Pty Ltd;
- Gabriel Hakim, Director, AgVet Energy;
- Kamrul Khan, Engineering Manager, Mayekawa;
- Carlos Lopes, Project Leader, Swedish Energy Agency;
- Trent Miller, A2W Manager, Mitsubishi Heavy Industries;
- Jan Rosenow, Principal and European Programme Director, Regulatory Assistance Project;
- Inge Sarunic, Team Lead – Sustainable Home, Sustainability Victoria;
- Takao Sawachi, Vice President, Building Centre of Japan;
- Leena Thomas, Professor of Architecture, University of Technology – Sydney;
- Andrew Tsakmakis, Mechanical Services Leader, ARUP; and
- Belinda Whelan, Director of Strategic Projects, Climate-KIC Australia.

We would like to thank the many EEC members and partners who have taken the time to review and refine the document – their feedback has been invaluable.

Project team

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Executive summary

Heat pumps are an energy-efficient technology for providing heating and cooling services across a range of residential, commercial and industrial applications. The high efficiency of electric heat pumps provides opportunities for reducing greenhouse gas emissions by reducing the amount of energy needed to provide heating and cooling services, as well as fuel-switching to electricity from fossil fuel energy sources.

Adoption of heat pump technology also unlocks the potential to deliver heating and cooling services with near-zero greenhouse gas emissions by integrating heat pumps with renewable energy.

Current adoption of heat pump technology in Australia is mixed. For some applications – such as refrigeration – heat pump penetration is near-universal. In others – like industrial processes requiring heat above 90°C, uptake is at an embryonic stage. The International Energy Agency (IEA) has highlighted the importance of heat pumps in a global transition to net zero, and the Australian Government has identified that heat pumps could play an important role as a low emissions technology.

Heat pumps transport heat from one place to another and are particularly useful as they can transport heat from a cooler place to a hotter place. Typically, heat pumps transfer heat to or from the outside environment through air, ground or water. Heat pumps that transfer heat to and from the air – air-source heat pumps – are the most common type. As heat pumps only transport energy, rather than convert one form of energy to another, they can be extremely energy efficient, with their coefficient of performance (COP) typically being greater than three. This is equivalent to an electrical energy efficiency of 300% or more.

Opportunities exist in Australia to deploy heat pumps into residential and commercial buildings for space heating and cooling as well as sanitary water heating. Near-term opportunities also exist to use heat pumps for low temperature (<90°C) industrial processes, with higher temperature applications likely to be available in the medium term. Significant energy and emissions savings are realised when heat pumps replace resistive electric heaters. Replacement of natural gas appliances can lead to significant emissions savings when heat pumps are integrated with low-emissions electricity. The ability of heat pumps to be paired with thermal storage can allow heat pumps to contribute to demand management and grid stability – by operating when renewable energy generation is highest, and switching off during periods of peak demand.

Modelling undertaken for this report identifies that the largest opportunity for emissions and energy savings exists in industrial processes, with a substantial emissions reduction potential also available in residential buildings. Commercial buildings are a smaller, but still significant opportunity. Early deployment of heat pump technology yields the greatest savings, with modelled scenarios indicating potential cumulative energy savings of up to **14,391 PJ** and emissions reductions of up to **746 Mt CO_2e** modelled to 2050.

The opportunities to reduce energy use and emissions modelled in this report are based on the potential of substituting heat pumps for resistive electric or natural gas heating equipment used for heating tasks in residential, commercial and building settings. Modelling has been undertaken on the basis of aggregate energy usage and illustrates the potential magnitude of energy and emissions savings under hypothetical heat pump adoption scenarios. Policy measures and other drivers that may accelerate heat pump uptake, and technical and other constraints that may hamper heat pump uptake have not been modelled. The levels of confidence surrounding the modelled estimations vary by sector.

For many applications of heat pumps, the underlying technology is mature and commercially available. However, research undertaken for this report identifies several barriers to heat pump adoption. Barriers include market failures such as information gaps and split incentives, as well as low commercial maturity in some sectors, leading to gaps in skills, experience and awareness of the benefits of heat pump technology. Heat pumps typically have a higher upfront cost than other technologies, which can be a barrier to deployment, even where the higher upfront cost is quickly defrayed through operational savings. Technical limitations and opportunity cost can also create barriers to installation of heat pumps, particularly in commercial and industrial settings.

Well-designed government policy and programs could help overcome these barriers. In the industrial sector, heat pumps are ready for deployment in some low temperature applications, but experience in deployment gained through pilot and demonstration programs would assist businesses in making informed decisions about the potential for heat pumps to save energy, emissions and money. Ongoing research and development (R&D) will help heat pump technology expand to other applications in the medium term.

In the residential sector, heat pumps are suitable for immediate deployment, and a residential deployment accelerator program that enables and facilitates installation of heat pump technology in households – particularly low-income and vulnerable households – could quickly realise substantial emissions reductions and energy savings, as well as associated health and comfort benefits for those households.

Commercial buildings offer a smaller opportunity to realise energy and emissions savings from heat pump deployment, but possess mature and well-developed frameworks to reduce emissions from building operations through the National Australian Built Environment Rating System (NABERS) and Commercial Building Disclosure (CBD) frameworks. Research for this report identifies that a lack of familiarity with heat pump technology amongst energy services professionals that work in commercial buildings – especially for building retrofits – remains a key barrier to heat pump deployment, and a series of demonstration retrofit projects could help build confidence, experience and capability to apply heat pump technology in commercial buildings.

Efforts to develop effective regulation and standards for heat pumps – particularly those aimed at consumers – will help build confidence in the market. Improving building codes and expanding energy performance disclosure frameworks will support a transition to net zero-ready buildings, with heat pump technology anticipated to underpin that transition. Training and workforce development will also be important in ensuring that heat pump technology is deployed with high standards of quality and safety.

Finally, ongoing policy development will help capture the greatest benefits from deployment of heat pump technology. Policy settings that help plan for integration of heat pump technology with renewable energy and the grid can maximise emissions reductions and reduce costs. The ability of heat pumps to be deployed flexibly can support grid stability and maximise the potential emissions reduction that renewable energy can provide. Government policies that support targeted R&D can also unlock future advances in heat pump technology, both through domestic advances and building capacity to rapidly adapt overseas innovations to Australian requirements.

Synthesis for policymakers

Heat pumps can contribute to achieving net zero

Governments of more than 130 countries – including Australia – have committed to, or are considering, achieving a target of net zero greenhouse gas emissions by 2050.[5] Achieving this target requires ambitious action, including deployment of new technologies that enable the production of goods and services with near-zero emissions.

Reducing emissions associated with energy use is the central component of achieving net zero across the world. Realising these reductions relies on two complementary strategies – improving energy efficiency and fuel-switching to less emissions-intensive energy sources.

Heat pumps are notable for their ability to do both; they improve efficiency and can facilitate fuel switching to electricity. Heat pumps are highly energy efficient and can deliver heating and cooling for a wide range of applications. Fossil fuel-based technologies can deliver heat with an energy efficiency of up to 95% and resistive electric technologies close to 100%. Heat pump technology can deliver three to five (or even more) units of thermal energy per unit of electrical energy used – an apparent efficiency of 300% or more.

Heat pumps achieve this remarkable feat by capturing heat energy from the environment, using refrigerants and an electric motor to transport this heat to where it is needed. Common applications for heat pumps include refrigeration, space heating and cooling and water heating. There are existing and emerging applications for heat pump technology across residential and commercial buildings, and industrial processes.

Heat pumps unlock a trifecta of abatement potential

Heat pump technology has three clear advantages that can rapidly unlock significant abatement. Electrically-driven heat pumps are highly **energy efficient**, can be powered by **renewable energy** such as on-site solar photovoltaics (PV), and can be coupled to low-cost thermal **energy storage** in the form of hot or cold water tanks. These characteristics underpin the potential for heat pumps to deliver heating or cooling with very low or zero operational emissions. This means that emissions associated with heating and cooling in some residential, commercial and industrial applications could be reduced by up to 100%.

Even if heat pumps are powered from the grid, their high levels of efficiency mean that they can reduce emissions compared to resistive electric technologies by **two-thirds** or more. When replacing fossil-fuel technologies, heat pumps can take advantage of the decarbonising electricity grid to drive emissions reduction.

5 Carver, D. 2021, *Global net zero commitments*, House of Commons Library, London.

Sizing up the opportunity

Australia has an opportunity to use heat pumps to achieve substantial savings in both emissions and energy usage. The *Heat Pump Energy and Emissions Savings Model* prepared for this report models a set of hypothetical scenarios that can be used to test the sensitivity of energy and emissions savings in varying deployment scenarios.

Over the next three decades, the modelled scenarios suggest that ambitious deployment of heat pumps across residential and commercial buildings and industrial processes could cumulatively reduce energy usage by up to **14,391 PJ** and save **746 Mt CO_2e** of greenhouse gas emissions by 2050.

These modelled savings are indicative of the magnitude of energy and emissions savings available. However, while the hypothetical heat pump adoption scenarios modelled for this report demonstrate a large potential opportunity, the actual energy and emissions savings realised from heat pump deployment will be dependent on a range of factors, including technological progress, the technical ability and availability of heat pumps to be installed for individual applications, broader economic and policy factors, as well as the actions of individual households and businesses. These factors are not considered by the *Model* developed for this report. The *Model* does consider the rate of decarbonisation of the electricity grid, however decarbonisation progress may not match predictions.

Confidence levels in the indicated energy and emissions savings vary by sector; heat pump applications in residential settings are relatively well defined and understood, while heat pump adoption in industrial settings is likely to be subject to a wider range of technical and economic constraints that could impact potential adoption.

The *Model* shows conclusively that the greatest abatement is realised through early action to encourage heat pump deployment. The modelled cumulative abatement available from early deployment is approximately twice the abatement that would be expected to arise from late deployment that occurred closer to 2050.

However, realising significant savings from heat pump technology would require an ambitious scale-up of deployment effort. This is true both within Australia and globally; in 2020, heat pumps met only 5% of global heating demand in buildings.[6] However, under the IEA's Net Zero by 2050 scenario, the number of heat pumps in the world will need to triple by 2030.[7]

Identifying opportunities

In Australia, heat pumps have application across residential and commercial buildings, as well as in industrial processes. In many cases, the underlying technology of heat pumps is mature and well-understood, but commercial maturity in Australia varies considerably.

In residential buildings, heat pumps find application in refrigeration, sanitary water heating and space heating and cooling. Products are commercially available in Australia to provide all these applications, but rates of market maturity and adoption vary. Significant emissions reduction opportunities remain through the replacement of gas and resistive electric space and water heating technologies with heat pumps.

In commercial buildings, the tasks suitable for heat pumps are identical to residential applications, albeit on larger scales. New commercial buildings can employ heat pump technology to be all-electric, providing the potential for emissions-free operation when integrated with renewable energy. Existing large commercial buildings are often equipped with centralised plant rooms for providing heating, ventilation and air-conditioning that frequently rely on gas boilers. Opportunities to replace gas boilers with heat pump technology in these buildings rely on mature technologies, however low levels of market expertise with retrofits means these opportunities are currently not being taken up.

In industrial processes, heat pumps can supply low-temperature heat (<90°C) for a wide range of processes in manufacturing and food processing such as washing, sterilising, drying, pasteurisation, concentration and space heating. Further development in heat pumps is showing their potential for application in medium-temperature applications (90°C to 150°C), and in the mining sector for alumina processing.

Modern heat pump technology can be deployed in all Australian climate zones. Suitable products are commercially available for most residential, commercial and industrial applications, although underdeveloped supply chains for novel applications in commercial buildings and industry mean that products are not always quickly accessible 'off the shelf' in Australia. Products range from consumer appliances that are available through retail channels, through to products that are best integrated into a building or industrial process with the assistance of a suitably qualified professional.

6 International Energy Agency (IEA) 2021, *Heat pumps – tracking report,* IEA, Paris.

7 Ibid.

Challenges to unlocking opportunities

Barriers to the deployment of heat pump technology exist in all sectors. These range from market failures such as information asymmetry, split incentives and limits to agency, as well as high upfront costs of heat pump technology, lack of consumer and installer awareness of the benefits of heat pumps, underdeveloped supply chains and low levels of skills and expertise in the marketplace.

In the residential buildings sector, barriers include upfront costs, split incentives between landlords and tenants or between builders and purchasers; information and expertise deficits amongst consumers, as well as a lack of skills, knowledge and incentive amongst trades and professions to highlight the benefits of heat pump technology to householders.

In commercial buildings, installation of heat pump technology is most easily done at the construction stage, when buildings can most easily be designed to capture the full benefits from heat pump technology. Retrofits of commercial buildings to install heat pump technology are more challenging, and demonstration projects to spread knowledge and expertise are required. For commercial buildings, business cases for installation of heat pump technology can weigh some factors – such as implementation risks, opportunity costs and expediency – more heavily, which can obscure the true costs and benefits of heat pump installation.

For industrial processes, challenges can include the advanced planning and effort required to retrofit an existing process to use heat pump technology. Investment decisions may be deferred until plant equipment requires urgent replacement, at which point expediency may dictate like-for-like replacement rather than investing the time to properly integrate heat pump technology into a process. Further challenges may include low levels of expertise, knowledge and awareness of the potential for heat pump technology to lower overall costs of operation and ownership.

Prioritising action

This report finds that **deployment of heat pumps in residential buildings is highly attractive** because it combines an opportunity for substantial and rapid abatement with immediately available products. Near-term efforts to accelerate deployment of heat pump technology in the residential sector will be rewarded with tangible, rapid reductions in energy usage and emissions. Levers to catalyse deployment could include existing incentive schemes such as the Renewable Energy Target and state and territory-based energy efficiency schemes, as well as improving regulation and standards, and developing literacy among relevant trades and professions.

The opportunity available in industrial processes is the largest modelled, but also requires longer-term effort. In some cases, heat pump technology could be deployed in manufacturing and food processing with existing technology and relatively small changes to processes. In other cases, more extensive piloting, development and demonstration will be required to confidently deploy heat pumps. However, the introduction of heat pump technology into a discrete industrial process – such as low temperature water heating – can yield very large savings in energy usage and emissions, making early attention to these processes a sound investment.

In aggregate, the emissions reduction **opportunity in commercial buildings is the smallest** of the three sectors modelled. However, this sector benefits from a **mature and well-developed framework for reducing emissions**, providing a strong foundation for introducing further low-cost policy measures that could enhance the contribution that commercial buildings make to achieving net zero. These could include expanding the coverage of disclosure regimes, as well as improved regulation and standards. Retrofitting heat pumps for heating in existing buildings poses particular challenges. Like industrial processes, government support for pilot projects is likely to be needed to develop the experience and knowledge necessary to scale up these applications.

Recommended actions

Governments and other organisations are well placed to facilitate and encourage an accelerated deployment of heat pump technology through a variety of policy levers. These range from:

- Investment in research and development;
- Strategic policy, regulation and standards;
- Partnership with other organisations to create knowledge, skills and awareness; and
- Provision of financial incentives to overcome barriers to adoption.

This report recommends a **priority action** for each sector:

- **Residential buildings:** A heat pump **deployment accelerator program** incorporating improvements to energy rating labels and performance standards, delivery of training and certification to installers, and government-backed installation of reverse cycle air conditioners (RCAC) and heat pump hot water systems (HPHWS) into public and low-income housing.
- **Commercial buildings:** A program of commercial building **demonstration retrofit projects** to build familiarity, expertise and market confidence in heat pump installation.
- **Industrial processes:** A process heat initiative including **planning, piloting and demonstration** of heat pumps into existing industrial sites, as well as ongoing **R&D** to broaden application of heat pumps into industrial processes.

These priority actions are accompanied by supporting recommendations that could help capture maximum benefits from deployment of heat pumps.

There are also cross-cutting areas for action that feature in all three sectors. These are

- Skills and workforce development;
- Innovation and knowledge-sharing;
- Effective regulations and standards; and
- Integration with renewable energy.

Skills and workforce development

A recurrent theme that interviewees have raised during the preparation of this report is a lack of comprehensive experience, familiarity and knowledge about heat pump technology across building, construction and engineering trades and professions, as well as associated energy services providers. This is a key barrier to adoption, as it is these businesses and professionals that will advise consumers and end users on choice of equipment for thermal services. Developing skills and experience of these professionals is critical to unlock the energy and emissions savings that heat pumps can deliver.

In the residential sector, an immediate priority is to provide with the skills and knowledge to install heat pump hot water systems, and to ensure that occupational licencing frameworks support safe and efficient installation processes. In commercial buildings, bringing experience with heat pumps to **architects, building designers, engineers and facilities managers** will enable efficient, all-electric building design that can harness the combined benefits of heat pumps and renewable energy. In industrial settings, up-skilling **engineers and refrigeration mechanics** to effectively integrate heat pump technology into manufacturing processes is a priority.

Heat pump manufacturers and industry bodies typically work to deliver professional development and certification for trades and professionals, particularly in new technology. However, this can represent a 'chicken and egg' paradox that may artificially inhibit adoption: manufacturers, trades and professionals may not be able to justify investing in training without a reasonable expectation of significant demand for the installation of heat pump technology, but demand may not materialise without a critical mass of trained professionals. Governments should consider integrated policy measures that pair incentives with upskilling programs to allow future demand to be serviced.

Innovation and knowledge-sharing

Ongoing innovation, including R&D and early deployment have been identified as a key enabler to unlocking the benefits of heat pumps. Importantly, any such knowledge must be shared. While heat pump technology is commercially available for a range of applications, ongoing activity in the innovation pipeline will enhance and expand economic and environmental outcomes from the technology.

Piloting and **knowledge-sharing** of early deployment to applications in manufacturing processes, as well as retrofits of existing commercial buildings, will accelerate the capacity of Australian professional services to offer high-quality, low-risk heat pump solutions to business and industry using currently available technology. Existing bodies, such as the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC) could be used to help facilitate pilot studies and knowledge dissemination, along with industry and professional bodies.

Continuing, well-targeted investment in **research and development** is important to expand the horizons of heat pump technology into new applications. While Australia will benefit from close engagement with international advances in heat pump technology at a global scale, ongoing R&D focused on Australian challenges will be important. This will include development of products matched to Australian conditions and requirements, and innovation in applying technology to Australian manufacturing and industrial processes.

Effective regulation and standards

Effective regulation and standards are important to support ongoing adoption and acceptance of heat pump technology. The confidence of consumers and other end users is built and reinforced through minimum standards, reasonable expectations of safety and quality and access to information about performance and suitability, assured by effective compliance mechanisms and remedies for non-performance. Regulations, rules and standards must also strike a careful balance between protecting the community, minimising regulatory burden that could hinder uptake, and not stifling innovation.

Appropriate **product standards** and regulation support consumers and end users to have confidence in selecting appropriate equipment to suit their needs. Minimum energy performance standards and energy labelling have been an effective tool to deliver energy efficiency improvements and could be extended to HPHWS as an immediate priority. Ongoing **improvements in building codes** support both improved quality and performance of buildings for occupants. Ambition in building codes to encourage electrification of as many buildings as possible through heat pumps and other technologies will enable further emissions reductions as on-site renewable energy and low-emissions grid electricity become increasingly available.

Rating and **disclosure** of building energy performance, both actual and possible, could enhance incentives for householders to invest in energy efficient household heating and cooling technologies. **Minimum rental standards** could also bring demand to the market, overcoming split incentives for investment in heat pump systems that significantly disadvantage tenants.

Integration with renewable energy

Opportunities exist to integrate heat pumps with renewable energy to further reduce emissions from thermal energy services. Smart energy management, thermal storage and load flexibility can also reduce operating costs and create new revenue streams for businesses, as well as enhance grid stability and reliability. **Innovation in technology and markets** that enables energy management activities to take advantage of the flexibility of heat pump technology is required. Efforts to integrate heat pumps with renewable energy sources will benefit from developing an understanding of how heat pumps will interact with the electricity networks in all sectors. Partnerships between government agencies, businesses and the heat pump industry to share knowledge and develop new opportunities will help drive ongoing innovation.

Catalysing immediately available deployment opportunities

Several commercially available heat pump technologies could realise immediate cost-effective emissions reductions. In particular, deployment of HPHWS and RCAC in residential settings to replace gas and resistive electric equipment, and replacement of gas boilers for heating in commercial buildings could deliver immediate abatement results.

Commonwealth, state and territory governments could enhance and expand existing energy efficiency schemes to incentivise heat pump deployment, and offer grants and other incentives for deployment of heat pump technology in low-income housing.

Incentivising deployment of low-temperature heat pumps, as well as investing in R&D, piloting and demonstration projects will unlock progressive decarbonisation of industrial processes. Other general stimulus measures could be utilised alongside these measures to further build the business case for capital investment in heat pump technology.

List of recommended actions

Priority recommendations

	Activity	Actor
R1	Develop and implement a heat pump deployment accelerator program for residential buildings, including: 1. Introduction of E3 labelling and MEPS for HPHWS systems; 2. Delivery of training and certification for tradespeople in residential heat pump installation; 3. Awareness and education campaign for households on choosing and maximising benefits from heat pumps; 4. Establish or expand programs to install heat pumps in low-income and vulnerable households; and 5. Expand and enhance financial incentives for residential heat pump deployment. Horizon: 1-5 years Areas: Strategy; Regulation and standards; Awareness; Deployment at scale	Commonwealth States and territories
C1	Fund a major new ARENA program to pilot and demonstrate heat pump retrofit projects in larger commercial buildings. Horizon: 1-5 years Areas: Experience and early deployment; Awareness	Commonwealth
I1	Develop and implement a national process heat initiative, including: 1. Strategy and timeline for decarbonising process heat; 2. A map and database of industrial fossil fuel boilers and burners, and model of electrical impacts of heat pump conversion; 3. A new program to pilot heat pump demonstration projects in manufacturers and food processors; and 4. A program of R&D for high-temperature heat pump applications and MVR technologies. Horizon: 5-10 years (initial phases); 10+ years (R&D) Areas: Strategy; R&D; Experience and early deployment; Awareness; Deployment at scale	Commonwealth

Supporting recommendations: residential buildings

	Activity	Actor
R2	**Align building codes and strategy with a trajectory for net zero-ready buildings, including:** **1. Continuing to advance the NCC and the *Trajectory for low energy buildings* and aligning the NCC to the *Trajectory*; and** **2. Ensure the NCC, NatHERS and BASIX encourage installation of more efficient appliances like heat pumps; and** **3. Remove barriers to heat pumps from building, planning and plumbing regulations.** Horizon: 1-3 years Areas: Strategy; Regulation and standards	Commonwealth States and territories
R3	**Introduce schemes to mitigate market failures in the property market that act as barriers to installation of heat pump technology, including:** **1. Mandatory disclosure of energy efficiency performance at point of sale and lease for residential homes; and** **2. Minimum standards for residential rental properties.** Horizon: 1-3 years Areas: Strategy; Regulation and standards	Commonwealth States and territories
R4	**Develop and implement a framework to optimally integrate heat pumps with the decarbonising electricity grid, including R&D, standards and platforms for market participation.** Horizon: 1-3 years Areas: Strategy; Integration with renewable energy	Commonwealth
R5	**Develop a comprehensive national residential retrofit strategy.** Horizon: 1-3 years Areas: Strategy	Commonwealth

Supporting recommendations: commercial buildings

	Activity	Actor
C2	**Align building codes and strategy with a trajectory for net zero-ready buildings, including:** **1. Continuing to advance the NCC and the *Trajectory for low energy buildings* and aligning the NCC to the *Trajectory*; and** **2. Ensure the NCC and NABERS encourage installation of more efficient appliances like heat pumps.** Horizon: 1-3 years Areas: Strategy; Regulation and standards	Commonwealth States and territories
C3	**Consider harmonising Australian standards for commercial heat pumps with international standards.** Horizon: 1-3 years Areas: Regulation and standards	Commonwealth
C4	**Harness the successful NABERS and CBD programs to power a transition to heat pumps in commercial buildings, by:** **1. Expanding the CBD program to new commercial building types, and requiring disclosure of the NABERS Renewable Energy Indicator; and** **2. Engage with commercial building owners through these programs to build awareness of heat pump technology.** Horizon: 1-3 years Areas: Regulation and standards; Awareness	Commonwealth
C5	**Establish a targeted ARENA program that supports commercial building owners to pilot demand management projects and share learnings.** Horizon: 1-3 years Areas: Strategy; R&D; Experience and early deployment; Integration with renewable energy sources	Commonwealth

Supporting recommendations: industrial processes

	Activity	Actor
I2	**Enable improved energy management at Australian industrial sites, including:** **1. Funding a national program to roll out metering and sub-metering infrastructure across industrial sites; and** **2. Support the adoption of energy management systems.** Horizon: 1-5 years Areas: Deployment at scale	Commonwealth
I3	**Consider actions to incentivise to industrial heat pump deployment, including:** **1. Reducing barriers to ERF participation, including new methods or guidance;** **2. Development of a co-investment scheme to assist industry to deploy heat pump and MVR technology; and** **3. Development of alternative methods of demonstrating emissions reductions where M&V is a significant barrier to scheme participation.** Horizon: 1-3 years Areas: Deployment at scale	Commonwealth (1-3) States and territories (2-3)

1

Introduction

Summary

- Heat pumps can provide heating and cooling services in manufacturing and residential and commercial buildings settings with **very high energy efficiency**.
- Deployment of heat pump technologies can **save energy and emissions**, helping achieve Australia's net zero emissions targets.
- Heat pump technology can be **integrated with renewable energy, amplifying emissions savings** and lowering operating costs.
- In Australia, heat pumps are **commercially mature** in some applications such as residential space heating and cooling, but less so in industrial applications.

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 per cent 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. When coupled with thermal storage systems – like hot water tanks – heat pumps can also play a role in supporting grid stability and increasing the penetration of renewables in Australia's electricity generation mix.

Greenhouse gas emissions from the burning of fuels for heat, steam or pressure made up 20% of Australia's emissions in 2020.[8] Analysis conducted for this report finds that up to 24% of Australia's non-transport energy is consumed to meet heating requirements at relatively low temperatures of up to 150°C – see *Section 3.3*. Serving these requirements with heat pumps would significantly reduce the amount of energy required, unlocking emissions abatement opportunities from both increased efficiency and pairing heat pumps with renewable energy sources.

8 Department of Industry, Science, Energy and Resources (DISER) 2020, *Australia's emissions projections 2020*, Commonwealth of Australia, Canberra, p. 24.

1.1 Policy context

The Australian Government has committed to achieving net zero emissions by 2050, and to reducing greenhouse gas emissions by 43% on 2005 levels by 2030.[9] The Australian Government is pursuing this objective with a suite of policies and programs that support cost-effective emissions reduction across the economy. State and territory governments are also actively implementing emissions reduction policies and programs that, if effective, will support the effort to meet Australia's emissions reduction targets.

Some of these policies are focused on particular sectors. Notably, the *Trajectory for low energy buildings* – and the *Addendum to the Trajectory for low energy buildings -Existing buildings* – outlines a national plan that aims to achieve zero energy and carbon ready buildings. Other policies are cross-sectoral. For example, the *Technology Investment Roadmap* is focused on driving down the cost of low- or zero-emissions technologies that can be deployed across the economy.[10]

An annual *Low Emissions Technology Statement* is a key part of the Roadmap. In recognition that electrifying heating and cooling with renewable energy sources has the potential to reduce Australia's emissions by a fifth,[11] the Australian Government has highlighted the role of heat pumps in achieving net zero emissions in the most recent *Low Emissions Technology Statement*.

1.2 Purpose of this report

The Australian Government Australian Government Department of Climate Change, Energy, the Environment and Water (DCCEEW) commissioned this report from the Energy Efficiency Council (EEC) and the Australian Alliance for Energy Productivity (A2EP) to identify opportunities to increase heat pump uptake across residential buildings, commercial buildings and industrial processes, including food supply chains. Further information about the scope of this report is provided in *Section 3.1*.

9 Australian Government 2022, *Australia's Nationally Determined Contribution Communication 2022*, Commonwealth of Australia, Canberra, p.3

10 Department of Industry, Science, Energy and Resources (DISER) 2020, *Australia's Technology Investment Roadmap: Discussion Paper*, Commonwealth of Australia, Canberra.

11 Department of Industry, Science, Energy and Resources (DISER) 2021, *Low Emissions Technology Statement 2021*, Commonwealth of Australia, Canberra, p. 44.

1.3 Heat pumps overview

Understanding how heat pumps work, the range of heat pumps available, their benefits, their limitations and their costs is essential to appreciate the role they can play in reducing energy bills and emissions.

Put simply, **heat pumps work by moving heat energy from one place to another, whilst also changing temperature**. Consider the reverse cycle air conditioners (RCAC) that many Australians are familiar with. In winter they pull thermal energy from the outdoor air into a room to heat it; in summer, they reverse, pulling heat out of the indoor air to cool the room. The unique ability to move heat from a colder place to a hotter place makes them useful in a wide range of heating and cooling applications. Heat pumps have various heat sources and sinks, services and applications, which are explored in detail in *Section 2*.

Heat pump technologies are very efficient, with the ability to produce high levels of thermal output compared to the energy input. The measurement of heat pump output is known as the coefficient of performance (COP), which is the ratio of output heat for each unit of input energy used to operate the heat pump – typically electrical energy. Typical heat pumps available for sale in Australia have a COP of three or more,[12] meaning they can supply at least three times as much energy as they consume. This compares with a maximum COP of one for a resistive electric heater, or less than one for gas boilers.

Heat pumps can be paired with renewable energy and thermal storage systems, which means they have the potential to play a central role in realising a least cost pathway to net zero for Australian buildings and industry. For example, combining hot water heat pumps with rooftop solar photovoltaics (PV) enables households to use their hot water system as thermal storage – effectively thermal 'batteries' – capturing more of the output of rooftop solar PV system for onsite use. Moreover, heat pumps have been recognised as the most efficient pathway to net zero for low temperature heat. According to the International Energy Agency (IEA), heat pumps powered by solar PV require five to six times less electricity than a boiler running on electrolytic hydrogen to provide the same amount of heating, when the energy losses that result from converting and transporting hydrogen are accounted for.[13]

Heat pumps can also improve business productivity. Modular, flexible manufacturing technologies using electricity and digitalisation are transforming manufacturing and are fundamental to cost-effective decarbonisation. Heat pumps can play a key part in this, providing manufacturers with process heat from renewable electricity. They can also re-energise rural and regional economies that lack access to gas grids, providing them integrated heating and storage solutions. See *Section 2.3.1* for further discussion on the benefits of heat pumps.

While heat pumps are in common use in applications such as refrigeration, residential air conditioning, and the cooling of commercial buildings, there are other applications where they are underutilised. Heat pumps are not commonly utilised for space heating in commercial buildings and process heating in industrial settings due to several barriers. These barriers range from behavioural to technical. See *Section 2.3.2* for further discussion on the limitations of heat pumps and barriers to their adoption.

12 Based on reverse cycle air conditioners registered on the *E3 database* in 2021.

13 International Energy Agency (IEA) 2021, *Global hydrogen review 2021*, IEA, Paris, p. 87.

1.4 Current state of the Australian heat pump market

In Australia, heat pump technology is at different stages of technological and commercial maturity for different applications and in different sectors. This report examines heat pump deployment in the residential buildings sector, the commercial buildings sector, and for the industrial sector.[14]

Heat pumps for **residential buildings** have the highest levels of commercial maturity, but adoption rates are low for some applications. In residential applications, heat pumps have a mature product ecosystem, well established supply chains, skilled trades familiar with the technology and are relatively widely deployed – such as in space heating and cooling.

Heat pumps for **commercial buildings** are technologically mature but have lower levels of commercial maturity in Australia. In many cases, commercial heat pump products are available on the global market, but skills to advise, design, integrate and deploy the technology in commercial buildings need development to achieve economies of scale.

In **industrial settings**, heat pumps are at a lower level of technological and commercial maturity. Some applications in industrial processing – such as water heating – are suitable for heat pump deployment with currently available technology. Applications requiring medium temperatures – 90-150°C – are at low levels of commercial maturity and require development of specialist skills and expertise. High temperature applications – greater than 150°C – are at relatively low levels of technological maturity both in Australia and around the world, with most in research and development (R&D) phases.

1.4.1 Heat pump adoption in Australia

In this report, heat pump adoption is considered in terms of a Rogers diffusion curve – **Figure 1**. The Rogers diffusion curve is a simplified model of how innovations are taken up throughout society, with different cohorts of actors adopting innovations at different stages. At very early stages of technological diffusion, a new technology is developed and adopted by innovators. As technological and commercial maturity of a technology develops, technologies are progressively adopted by different cohorts, from early adopters through to the early majority, late majority and finally laggards. Adoption of innovations occurs on a range of time scales, from days or weeks to decades or centuries, and is influenced by a range of social, economic and technological factors. External actors – such as governments – are also able to influence the rate of adoption – see **Box 1**.

In Australia, adoption of heat pump technology ranges from near universal – such as for refrigerators, at the extreme right of the curve – to almost non-existent – for higher temperature industrial heating, at the extreme left of the curve.

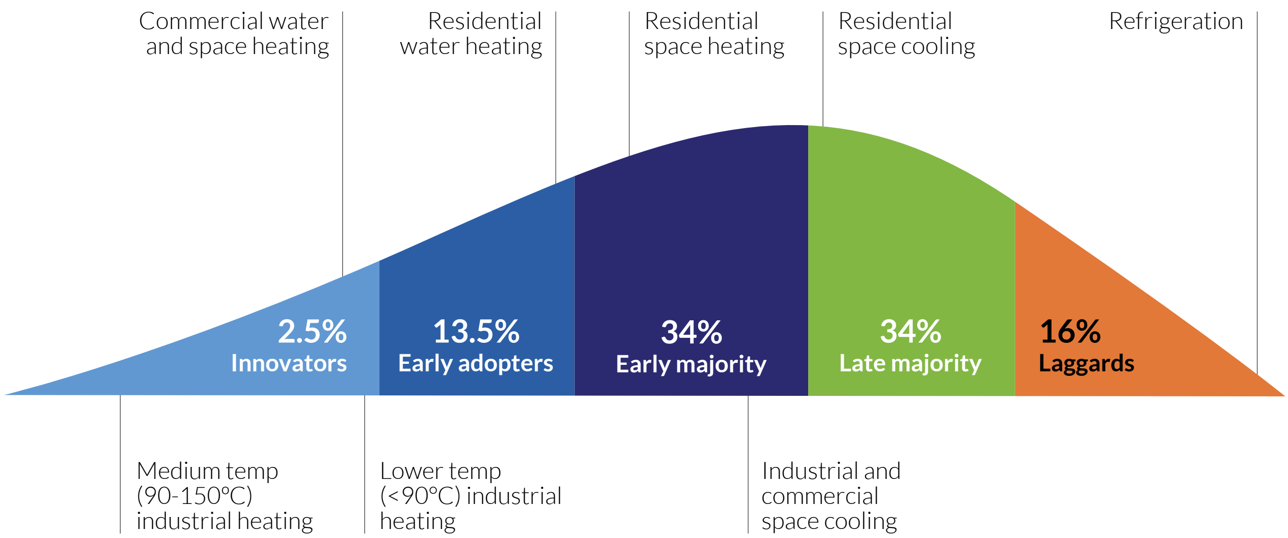


Figure 1 Estimated adoption of heat pump technologies in Australia along Rogers diffusion curve, a simplified model of how new technologies are adopted across economic sectors

14 For the purposes of this report, the industrial sector is taken to mean manufacturing and food processing, including mineral processing.

Very limited quantitative data is available regarding heat pump penetration in Australia, and gathering new quantitative data was out of scope for this report. Consultation for this report has identified that heat pumps are installed in the greatest numbers for:

- Refrigeration in buildings, manufacturing and food supply chains;
- Residential space heating and cooling; and
- Space cooling in commercial buildings and on manufacturing sites.

Heat pumps are less commonly used for:

- Heating water in all sectors;
- Space heating in large commercial buildings; and
- Heating loads in manufacturing processes.

BOX 1: Governments can influence adoption rates

The Rogers diffusion curve (**Figure 1**) is a simplified model of how new technologies are adopted across economic sectors. Government investment in R&D and demonstration – by bodies such as the Australian Renewable Energy Agency (ARENA) – can create partnerships with 'innovators' willing to test new technologies and approaches to energy management.

Government investment in deployment via targeted grants and capability building can move technologies and other solutions along the diffusion curve. These efforts can encourage 'early adopters' to take the plunge on new technology, building an enabling ecosystem of product and service providers around them.

The appropriateness of government intervention to drive additional activity by the 'early majority' and beyond varies dramatically between sectors and technologies. In some cases, no further government action will be necessary as a self-sustaining market will have been established.

Elsewhere, other levers like investment from bodies such as the Clean Energy Finance Corporation (CEFC), incentives – like those provided by state-based energy efficiency schemes – or standards – such as minimum energy performance standards – will be necessary to drive further activity along the diffusion curve.

In many applications, heat pumps compete with fossil fuel-based technologies that have very high levels of commercial maturity. The historical availability of abundant and low-cost fossil fuels has contributed to these technologies becoming the norm in Australia, allowing stable supply chains and market experience to develop. Further, successive government policies across Australia have focussed on supply-side energy market reforms to enhance energy affordability and reliability, with comparatively less attention paid to demand-side efficiency improvements – such as heat pump technology. This has resulted in lower levels of consumer awareness and, in some instances, unfavourable policy and regulatory settings.

Current policies and programs to support the adoption of heat pumps in Australia largely target the residential sector – see *Appendix 1* for a list of current policies and programs both in Australia and around the world. However, policymakers in Australia are turning their attention to the opportunity to drive deployment of heat pumps in commercial buildings and industrial settings, through mechanisms such as state-based energy efficiency schemes.

Learn more about the state of the Australian heat pump market in residential buildings, commercial buildings and industrial settings in the sector-specific Sections 5, 6 and 7.

1.5 Current state of the international heat pump market

In other countries, heat pumps are common in residential and small commercial buildings. Australia can draw on the experience of nations around the world to guide the expansion of heat pump adoption domestically.

For example:

- **Japan** has developed highly efficient air-source heat pump hot water systems;
- Strong policy signals in **China** led to widespread deployment of ground-source heat pumps for heating of public buildings; and
- Despite its cold climate, **Sweden** has built economies of scale through incentives for the deployment of ground-source heat pumps for residential purposes.

The choice of heat pump technology that has been adopted in international markets has been influenced by several factors, including:

- Technological and commercial maturity, including cost;
- Climate;
- Availability of alternative fuels and their cost relative to electricity;
- Degree of concern around energy security;
- Workforce capability; and
- National energy and climate policies.[15]

Rigorous standards for performance, noise and safety of heat pumps are in place in Europe, and robust supply chains exist with manufacturers based in Europe, the United States of America (US) and Asia. However, in most jurisdictions, one or more of these factors continue to pose a barrier to the wholesale adoption of heat pumps across the economy.

Recognising that heat pumps will play a crucial role in their decarbonisation strategies, international policymakers are acting to address these factors. Significant effort is being made in Europe and North America on two fronts:

- Driving the rapid deployment of technologically mature heat pump technologies; and
- Expediting the development of more nascent technologies through investment in R&D and demonstration.

The rate of policy development and technological improvement in Europe, North America and Asia is rapidly accelerating. Programs and policy measures are already in place internationally, including:

- Training programs for installers;
- Incentives for renewable heat;
- Building codes that support the adoption of heat pumps; and
- Retrofit programs to replace gas-fired heating.

See *Appendix 1* for a comprehensive list of programs and policies that support the adoption of heat pumps in Australia and overseas.

15 Nowak, T. 2018, *Heat pumps: Integrating technologies to decarbonise heating and cooling*, European Copper Institute, Brussels.

1.6 Future potential: unlocking the opportunity

This report reviews the opportunity to realise low-cost energy and emissions abatement in homes, commercial buildings, and industrial processes through the increased uptake of heat pumps. Working with industry, governments can support Australian families and businesses to reap the benefits of heat pumps through a well-designed suite of policies and programs that draw on best practices from overseas and are relevant to the local market.

Identified actions to accelerate heat pump deployment fall into the following broad categories, as depicted in **Figure 2**:

1. **Strategy**;
2. **Research and development (R&D)**;
3. **Experience and early deployment**, including pilot projects;
4. **Regulation and standards**;
5. **Integration** with renewable energy sources;
6. **Awareness**, including guides, training and campaigns; and
7. **Deployment at scale**, including enabling incentives.

Opportunities are explored in more detail in *Section 4*, with more detailed information on residential buildings, commercial buildings and industrial processes found in Sections *5*, *6* and *7* respectively.

Acting on these opportunities will enable heat pumps to play an integral role in Australia's achievement of net zero emissions by 2050.

Figure 2 Seven areas of opportunities with activities that will enable heat pumps to play an integral role in Australia's achievement of net zero emissions by 2050

2 Background and technical information

Summary

- Heat pump technology **delivers heating and cooling services with very high levels of energy efficiency**. Common heat pump tasks are water heating and space heating and cooling.
- For heating services, **heat pumps use much less energy** than gas or resistive electric heating, which can reduce energy bills and emissions.
- Heat pump technology **can be integrated with renewable energy and used flexibly**, which can further increase emissions savings and support grid stability.
- Heat pumps invariably **deliver operating cost savings** when compared to competing technologies but can have higher upfront costs compared to resistive electric or gas technologies.
- Heat pump technology **can be used across Australia's climate zones**, but proper system selection is important to ensure consistent and efficient operation.

Heat pumps are being embraced around the world as a key component of the transition to renewable energy and the transformation to net zero emissions. With research and innovation around heat pumps accelerating as major economies work to decarbonise, Australia can leverage these developments for effective emissions abatement while improving reliability in electricity supply, and competitiveness of Australian businesses through increased productivity.

BOX 2: Key terms

Coefficient of performance (COP)
A metric for how much energy is required for an appliance to produce a certain amount of useful heat energy. A higher COP indicates a higher level of energy efficiency. An appliance with a COP of 0.8 will produce 0.8 units of heat energy for every one unit of input energy used to operate the appliance – such as electricity or gas – while an appliance with a COP of three will produce three units of heat for every one unit of input energy.

Gas boiler
An appliance for producing hot water and/or steam by combusting natural gas. Boilers have COP of around 0.8, with some high efficiency condensing boilers having a COP of up to 0.95.

Heat pump
A mechanical device for transporting heat from one place to another. Usually powered by electricity, but other energy sources are possible. Heat pumps typically have a COP of between three to five, but can be higher or lower.

Hot water system
An appliance to heat water for sanitary needs. Typically heats water to at least 60°C and can be powered by a range of energy sources.

Process heat/steam
In manufacturing or other industry, heat or steam is often needed to undertake a step in the manufacturing process. Heat and steam have traditionally been supplied by gas or resistive electric boilers.

Heat source/sink
A heat pump transfers heat energy from a source of heat to a sink. Sinks and sources can be the ground, air, water, or other fluids:

- **Air-source heat pumps (ASHP)** transfer heat to and from the atmosphere by circulating air across a coil containing refrigerant;
- **Ground-source heat pumps (GSHP)** transfer heat to and from the ground by circulating refrigerant through coils buried in the ground, where the temperature is more stable than the atmosphere; and
- **Water-source heat pumps (WSHP)** transfer heat to and from a body of water – such as a tank, reservoir or lake – by submerging refrigerant coils in that body of water.

Resistive electric heating
A method of heating that requires running electric current through wires that heat up by resisting the flow of electricity. This converts electrical energy into heat energy directly, rather than using electrical energy to move heat energy – as in a heat pump. Resistive electric heating is used for both water and space heating, with a COP of one or slightly less.

Reverse cycle air conditioner (RCAC)
An appliance that can provide both space heating and cooling services by directly heating and cooling air using a single heat pump in which the refrigerant flow can be reversed.

2.1 Services and applications of heat pumps

Heat pumps can be utilised in a variety of ways in a range of sectors across the economy. This report and the associated *Heat Pump Energy and Emissions Savings Model* – see *Section 3.2.3* – focus on services and applications in residential buildings, commercial buildings and the industrial sector, including:

- Sanitary hot water;
- Space heating and cooling;
- Pool heating;
- Refrigeration;
- Process water and product heating;
- Process air heating; and
- Mechanical vapour recompression (MVR) in alumina – see *Section 7.2.3*.

The *Model* focuses on these sectors and services as they are where the greatest opportunity exists – see *Section 3.2.3*. Heat pumps can also be used in sectors such as agriculture, water and waste, and transport; these sectors and their specialised applications are not covered in this report.

For detailed information on the services and applications of heat pumps in:

- Residential buildings – see *Section 5.2*;
- Commercial buildings – see *Section 6.2*; and
- Industrial processes – see *Section 7.2*.

2.2 Defining heat pumps

Heat pumps can harness thermal energy from a range of sources, providing heating and cooling services that can be used across a range of applications. This report focuses on heat pumps that use electrical energy to drive the heat pump's compressor, which is the 'engine' of a heat pump.

2.2.1 How heat pumps work

Heat pumps are mechanical devices that transport heat energy from one place – the heat **source** – to another place – the heat **sink**. A simplified schematic is shown in **Figure 3** Principally, this process is used to heat or cool air or water.[16] As heat pumps *transfer* existing heat energy from one place to another, they are different from conventional appliances like gas boilers or resistive electric heaters that convert one form of energy to another. This means that heat pumps can transfer more heat energy than it takes to operate the heat pump.

The configuration of heat sources and sinks varies, depending on the heat pump's service and application. For example, in an air-source heat pump (ASHP) hot water system, heat drawn from ambient air – the **source** – is transferred into a hot water tank – the **sink**.

Reverse cycle air conditioners (RCAC) use a similar process for space cooling: heat energy is removed from the heat source – i.e. the air within a room – and released as waste heat to the sink – the outside ambient air. This process is reversed for space heating by RCACs.

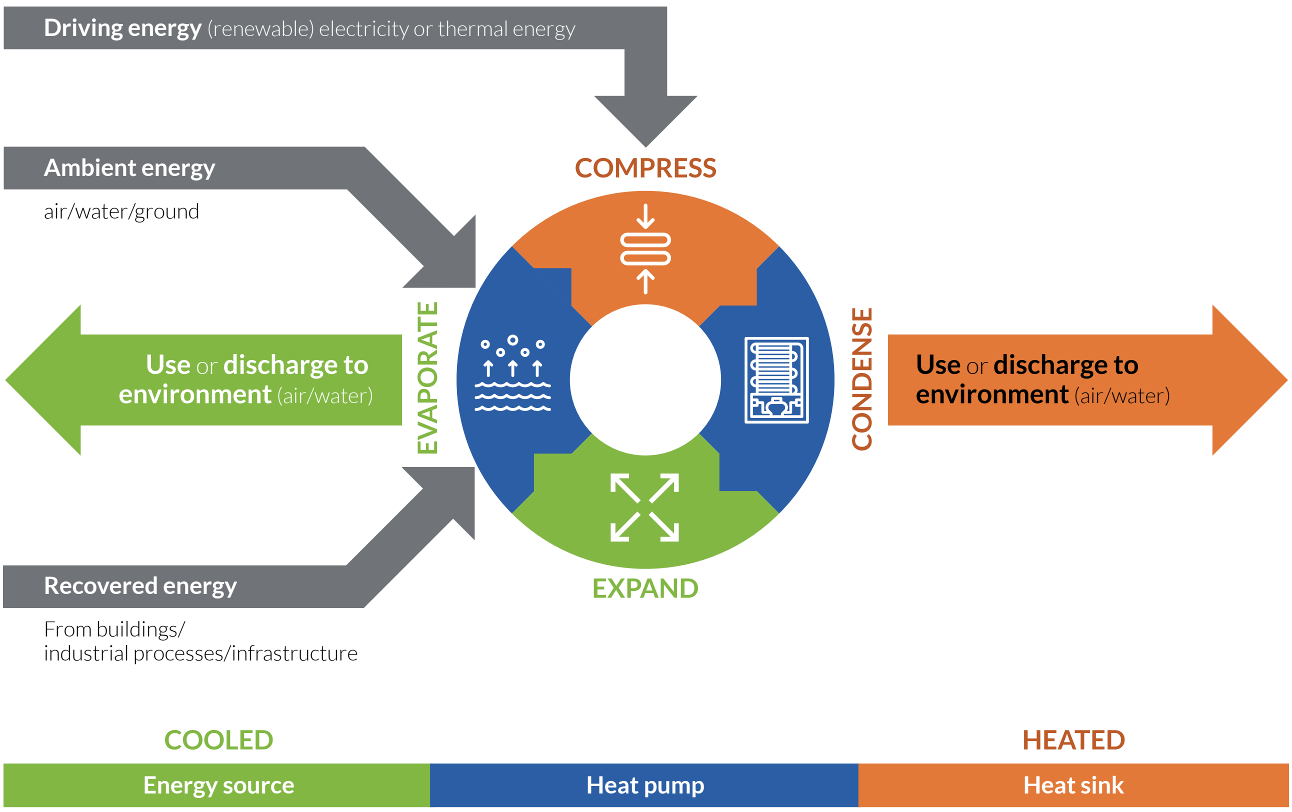


Figure 3 Simplified diagram of a heat pump.

Source: Nowak 2018

16 Lovegrove, K. et al. 2019, *Renewable energy options for industrial process heat*, Australian Renewable Energy Agency (ARENA), Turner, ACT.

Unlike passive thermal systems where heat energy is always transferred from a hotter to a cooler place – such as where a cooling fluid cools a hot engine – heat pumps can be used to transfer heat from a cooler place to a hotter place – such as transferring heat from a cold refrigerated cabinet to the warmer surrounding air.

This is achieved by taking advantage of compression and expansion of a working fluid – or refrigerant – that *transfers* heat energy from the heat *source* to the *sink*. Heat transfer occurs through four separate processes, joined into a cycle:

1. Low-temperature refrigerant is passed through an **evaporator**, where it absorbs heat energy and turns into a gas – for example, in an air-conditioner, the evaporator is located in the room to be cooled;
2. The gas is passed through an electric **compressor** that compresses the gas, further raising its temperature;
3. The hot, gaseous refrigerant is then passed into a **condenser**, where it gives off heat and the refrigerant condenses back to a liquid – in an air conditioner, the condenser is located in the outside air; and
4. The liquid is then passed through an **expansion** valve, which reduces the pressure of the refrigerant, lowering its temperature, ready to go through the cycle again.[17]

This cycle is repeated endlessly to keep moving heat from the **source to the sink**.

The ability of a heat pump to transfer heat from cooler places to hotter places is due to the particular properties of the refrigerant. Refrigerants are carefully selected to be appropriate for the task, and usually have a relatively low boiling point.[18] See *Section 2.5.1* to learn more about refrigerants.

As noted in *Section 1.2*, the efficiency of heat pumps is measured by the coefficient of performance (COP), which is the ratio of thermal energy output to input energy used to operate the appliance.[19] A higher COP indicates a greater amount of thermal energy output relative to input energy is provided by the heat pump.

The relatively high COP of heat pumps is key to their utility: while gas heaters can achieve efficiencies up to 95% – a COP of 0.95 – and resistive electric heaters can achieve close to 100% – a COP of 1 – heat pumps typically achieve a COP of three or more. This means that for every unit of electrical energy a heat pump consumes, it can produce three or more units of thermal energy.

2.2.2 Types of heat pumps

Heat pump types are generally distinguished by heat source and heating and/or cooling application. For example, an ASHP hot water system refers to a heat pump that uses heat from the outdoor air to heat water. The ideal heat pump for a given situation depends on the desired application, local climate and comparison with alternative thermal energy sources.

Heat pumps may source heat from:

- Ambient air;
- Water or other liquids;
- Ground heat; or
- Waste heat captured from other processes.

In Australia, ASHP are the dominant type, with deployment of ground and water-source heat pumps limited to niche applications.

Air-source heat pumps

Air-source heat pumps (ASHPs) transfer heat to and from the atmosphere – typically, outdoor air is used as the heat source or heat sink. Heat energy is available in any substance with a temperature greater than absolute zero, or -273.15°C. That means the heat energy that ASHPs need to function is present in outdoor air, even in climates with colder temperatures.

ASHPs used to heat water – particularly for domestic or sanitary purposes – are referred to as heat pump hot water systems (HPHWS). ASHPs used to heat and cool indoor air are referred to as reverse cycle air conditioners (RCAC). In Australia, commercially available RCAC systems have COPs of between 3 to 5.5, and heat pump hot water systems have typical COPs of 3 to 5.[20]

17 Bannister, P. n.d., *Heat pumps explained*, Automatic Heating.

18 Nowak, T. 2018, *Heat pumps: Integrating technologies to decarbonise heating and cooling*, European Copper Institute, Brussels.

19 Lovegrove, K. et al. 2019, *Renewable energy options for industrial process heat*, Australian Renewable Energy Agency (ARENA), Turner, ACT.

20 Based on COP values for reverse cycle air conditioners registered on the *E3 database* in 2021, and a survey of self-reported COP values for HPHWS available in Australia in 2021.

Both HPHWS and RCAC can be used in residential and commercial buildings and can significantly reduce energy usage and emissions. The exact savings will depend on climate, choice of equipment and the fuel used by the technology to which the heat pump is compared. For example, an efficient RCAC used in Melbourne to heat a room can use just 21% of the electricity that a resistive electric heater would use to heat the same space – reducing emissions by up to 79%.[21]

Ground-source heat pumps

Ground-source heat pumps (GSHP) – or geothermal heat pumps – use a working fluid loop that is buried in the ground and transfers heat to and from the earth. This is due to the stable, mild temperature that is found just underneath the surface of the ground year-round. In winter, energy can be extracted from the ground and transferred to the air inside of a building via a transfer fluid to provide heating; in summer, energy can be extracted from the air inside a building and transferred to the ground to effectively cool a building. GSHPs have an average COP of 3.5 to 4.[22] As the underground temperature is relatively unaffected by atmospheric conditions, GSHPs perform better than ASHPs when the ambient temperature is very low, and have found the widest deployment in cold climates, such as in Sweden and northern China.[23,24]

Water-source heat pumps

Water-source heat pumps (WSHP) take advantage of the heat present in bodies of water or other liquids. Sources of water such as lakes contain heat at more stable temperatures than outdoor air. However, these types of heat pumps require proximity to a body of water. The stable temperature and good thermal conductivity of water – compared to air – means that WSHPs are more efficient and have an average COP of 4.5.[25] WSHPs can be used for space and water heating and cooling in both residential and commercial buildings.

Waste heat pumps

In some applications such as industrial process heating, heat pumps can be used to capture and re-use process heat which would otherwise be wasted.[26] Waste heat can be captured and re-heated to the required temperature, reducing energy waste and avoiding additional energy usage.[27,28]

Heat pumps are very effective at recovering latent heat from fluids by condensing them. For example, the water vapour in the humid exhaust air of an aquatic centre can be condensed, recovering a significant amount of energy that would otherwise be wasted.

Heat pumps can also replace boilers for steam production in industrial processes.[29] Active R&D efforts – particularly in Europe – are producing heat pumps that deliver increasingly high temperatures, with prototype and limited production units achieving temperatures up to 160°C.[30] Even higher temperatures may be feasible in the future.

Comparison of heat pump types

Each heat pump type has advantages and disadvantages as summarised in **Table 1**. In general, ASHPs are typically the least expensive, but ground- and water-source heat pumps are more efficient and more suitable in some applications. Additional types of heat pumps exist for specific applications – such as MVR, which is discussed in *Section 7.2.3*.

21 Based on Sustainability Victoria 2021, *Calculate heating running costs,* Victorian Government, Melbourne.

22 Guar, A., Fitiwi, D., and Curtis, J. 2021, *Heat pumps and our low-carbon future: A comprehensive review*, Energy Research & Social Science, 71: 1-18.

23 Mattinen, M., Nissinen, A., Hyysalo, S., and Juntunen, J. 2014, *Energy use and greenhouse gas emissions of air-source heat pump and innovative ground-source air heat pump in a cold climate*, Journal of Industrial Ecology, 19(1): 61-70.

24 Yang, L. 2020, *Heat pump market development in China*, HPT Magazine, 39(3): 14-17.

25 Guar, A., Fitiwi, D., and Curtis, J. 2021, *Heat pumps and our low-carbon future: A comprehensive review*, Energy Research & Social Science, 71: 1-18.

26 Lovegrove, K. et al. 2019, *Renewable energy options for industrial process heat*, Australian Renewable Energy Agency (ARENA), Turner, ACT.

27 US Department of Energy 2003, *Industrial heat pumps for steam and fuel savings: A best practice steam technical brief*, US Department of Energy, Washington, DC.

28 Evans, M. et al 2021, *Research theme B3 Electrification and renewables to displace fossil fuel process heating – Opportunity assessment*, RACE for 2030, Canberra.

29 Australian Alliance for Energy Productivity (A2EP) 2018, *A guide for business: Replacing steam with electricity technologies to boost energy productivity*, A2EP, Ultimo, NSW.

30 Evans, M. et al 2021, *Research theme B3 Electrification and renewables to displace fossil fuel process heating – Opportunity assessment*, RACE for 2030, Canberra, p. 65.

Heat pump type	Examples	Advantages	Disadvantages	COP[31]
Air-source (ASHP)	**Air-air:** • Refrigerator • Reverse cycle air conditioner (RCAC) **Air-water:** • Heat pump hot water system • HVAC chiller • Pool / spa heater • Industrial process water heater	• Freely available heat source (ambient air) • Lowest upfront cost	• Least efficient heat pump type • Performance varies with season / weather event • Can ice-up in frosty conditions	3
Ground-source (GSHP)	**Ground-air:** • Space heating and cooling system **Ground-water:** • Hydronic heating system	• High efficiency due to stable ground temperature • Performance not affected by weather, season or frost	• High upfront cost due to excavation or boring for coils • Need to bury coils rules out some applications	3.5-4
Water-source (WSHP)	**Water-air:** • Space heating and cooling system • Waste heat recovery system **Water-water:** • Industrial process heat recovery system	• Very high efficiency due to stable water temperature • Performance less affected by weather conditions	• Body of water required near heat pump • Higher upfront cost	4.5

Table 1 Comparison of heat pump types

Note: Although a standardised COP has been quoted for each heat pump type, COPs can vary substantially depending on a range of factors. For example, COPs of RCAC ASHPs on the Australian market vary between 3 and 5.5, or even higher in some cases.

31 Guar, A., Fitiwi, D., and Curtis, J. 2021, *Heat pumps and our low-carbon future: A comprehensive review*, Energy Research & Social Science, 71: 1-18.

2.3 Valuing heat pumps

2.3.1 Benefits

Energy efficiency reduces emissions

Australia's long term emissions reduction plan has highlighted energy efficiency as a crucial element of the transition to net zero emissions, particularly in the buildings sector.[32] Indeed the International Energy Agency (IEA), projects that energy efficiency represents more than 40% of the global emissions abatement needed by 2040.[33]

Heat pumps can have very high energy efficiency compared to other heating and cooling technologies. Harnessing this efficiency dividend is critical in the transition to net zero, especially between now and 2030. Australia's electricity grids rely on large fossil fuel generators, which are expected to remain a substantial part of the mix of electricity generation until the early 2040s.[34] Replacing legacy technologies like electric resistive heaters with heat pumps for services such as space heating and hot water generates an immediate and significant emissions reduction by utilising less grid supplied electricity for the same service.

Heat pumps reduce emissions through fuel switching and flexibility

Widespread electrification is seen as a key strategy to reduce greenhouse gas emissions in a range of sectors.[35] Emissions from the burning of fuels for heat, steam or pressure make up 20% of Australia's emissions.[36] Deployment of heat pump technology can allow for efficient and practical electrification of heating and cooling tasks, permitting fuel-switching from other, more greenhouse gas intensive fuels used for heating.

Further, electrification of heating and cooling tasks allows for fuel choice, as the electrical energy used to power heat pumps can be flexibly drawn from a range of sources such as natural gas, hydrogen, biomass, solar, wind, hydro, allowing least-cost and least-emissions operations.

Heat pumps leverage renewable energy

While the transition to lower-emissions electricity is progressing at a rapid pace, very high penetrations of renewable energy remain some years off.[37] Consequently, a window of opportunity remains to prepare the electricity grid for high-renewable generation.

Heat pumps can be paired with renewable energy to lower emissions, with the benefit increasing over time as the grid decarbonises. Effective pairing of heat pumps with onsite or grid supplied renewable energy can completely decarbonise some heating processes.

Matching heat pump use with onsite solar PV generation can significantly lower emissions and running costs. Australia is particularly well positioned to take advantage of this opportunity given the highest global levels of solar irradiance,[38] and as over one quarter of households have installed rooftop solar PV, a number that continues to go up.[39]

Heat pumps support demand flexibility

Electrification of large commercial and industrial loads with heat pump technology opens new opportunities for demand response – precise load shaping in response to incentives. Some – but not all – commercial and industrial heat pump applications are amenable to being used flexibly, particularly when coupled with thermal storage.

This can help bodies such as the Australian Energy Market Operator (AEMO) respond to grid conditions and constraints. Demand response opportunities in Australia include the Wholesale Demand Response Mechanism (WDRM) and the Frequency Control Ancillary Services (FCAS) markets, amongst others.[40] The flexibility offered by these markets can support grid stability, helping to manage peaks and troughs in variable renewable energy (VRE) production over the course of a day.

32 Department of Industry, Science, Energy and Resources (DISER) 2021, *Long Term Emissions Reduction Plan*, Australian Government, Canberra.

33 Fischer, A. 2021, *How energy efficiency will power net-zero climate goals*, IEA, Paris.

34 See AEMO 2022, *2022 integrated system plan*, AEMO, Melbourne, p.39. The share of non-renewable energy in the National Electricity Market is expected to be 17% by 2030-31, dropping to 4% by 2040, under the 'Step Change' scenario, which is considered most likely.

35 Beyond Zero Emissions (BZE) 2018, *Zero carbon industry plan: electrifying industry*, BZE, Melbourne; Climateworks Australia 2020, *Decarbonisation futures: solutions, actions and benchmarks for a net zero emissions Australia*, ClimateWorks Australia, Melbourne, pp. 8-9.

36 Department of Industry, Science, Energy and Resources (DISER) 2020, *Australia's emissions projections 2020*, Commonwealth of Australia, Canberra, p. 24.

37 Australian Energy Market Operator 2022, *2022 integrated system plan*, AEMO, Melbourne, p.45.

38 Geoscience Australia n.d., *Solar Energy*, Australian Government, Canberra.

39 Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2021, *Australia installs record-breaking number of rooftop solar panels*, CSIRO, Canberra.

40 Energy Briefing n.d., *Demand response 101*, Energy Efficiency Council, Melbourne.

Larger-scale businesses and industrial users that transition to heat pump technology will have the option of participating in these and other electricity market mechanisms that support grid stability. In the future, there is likely to be opportunities for residential and small- and medium-sized enterprise (SME) customers to participate as well, by enabling their heat pumps to function as demand response enabled devices (DREDs).[41] The load from DREDs can be aggregated and managed remotely in ways agreed to by the customer, who receives a payment or incentive in recognition of the value this provides to the system.

Thermal storage supports grid stability

Heat pumps also enable renewable energy to be captured and stored as thermal energy for later use – for example hot water heating, or the pre-heating or -cooling of a space. Thermal storage in hot water tanks or internal thermal mass is practical with commercially mature technology. It is relatively low-cost in comparison with electrical storage, and can be used flexibly.

This means that heat pumps can be programmed to operate when grid demand is low and VRE generation is high – such as in the middle of the day – and ramp down or switch off when grid demand is high. This can be achieved in a variety of ways: a simple timer, which is already found on many heat pump hot water systems, through to advanced, smart, grid-aware systems that can dynamically respond to grid conditions. At scale, pairing renewable energy with thermal storage can help deal with issues associated with both minimum and peak demand, supporting grid stability.

However, a broad transition to electric heat pumps will have impacts on the electricity grid. Substituting gas heating with electric heat pumps is likely to increase electricity demand, while replacing resistive electric heating appliances with heat pumps should have the effect of lowering demand. The aggregate effect on a transition to heat pumps on the grid has not been modelled in this report and is likely to depend on factors including economic and policy drivers, local circumstances and business and consumer behaviour.

Lower energy bills

Heat pump technology can provide efficient heating, cooling and water heating for households, businesses, and industry. Heat pumps provide the opportunity to significantly reduce total energy costs for these processes through using less energy, particularly where resistive electric appliances are replaced by heat pump technology.

Sustainability Victoria estimates that the running costs of heating a room using an efficient RCAC costs less than a quarter of using a resistive electric appliance.[42] This can reduce energy costs for those who have access to the technology, which is particularly important for those who may bear greater physical, social or economic costs of climate change, including the elderly or those on low incomes, due to greater financial and physical vulnerabilities.[43]

As with other energy efficiency measures, installation of heat pumps can produce multiple benefits, such as supporting healthier living conditions by allowing householders to effectively heat and cool their homes at relatively low cost.[44]

Replacing gas equipment with heat pump technology may also lead to lower energy bills, depending on the relative price difference between electricity and gas. In the last decade, gas prices in eastern Australia have increased as a result of being linked to export markets,[45] and have spiked in early 2022 due to conflict in Europe.[46] In new homes served by the National Electricity Market (NEM) – which is a wholesale commodity exchange for electricity spanning Australia's eastern and south-eastern coasts – it is almost always more cost-effective to build an all-electric house, and in many cases switching existing gas appliances to efficient electric appliances – such as heat pumps – will leave householders better off.[47] Deploying heat pump technology may also avoid costs of installing gas connections and infrastructure, and ongoing gas connection costs, particularly for new buildings.

For households and businesses with onsite solar PV, even greater cost savings are possible where heat pumps can be run using energy generated by onsite solar PV. This provides near-zero marginal cost heating and cooling services.

41 Farnsworth, D., Shipley, J., Lazar, J., and Seidman, N. 2018, *Beneficial electrification: Ensuring electrification in the public interest*, Regulatory Assistance Project, Montpelier, VT.

42 Sustainability Victoria 2021, *Calculate heating running costs*, Victorian Government, Melbourne.

43 Australian Council of Social Service (ACOSS) and Brotherhood of St Laurence (BSL) 2018, *Tackling climate change and energy affordability for low-income households*, ACOSS, Strawberry Hills, NSW.

44 Energy Efficiency Council (EEC) 2021, *Ensuring quality control and safety in insulation installation: A research report to support an industry-led roadmap for healthy, comfortable buildings*, EEC, Melbourne.

45 Energy Briefing 2021, *Navigating a dynamic energy landscape: a briefing for Australian businesses – fourth edition*, Energy Efficiency Council, Melbourne, p. 9.

46 Energy Briefing 2022, *'National energy markets update: gas prices continue to rise with Russia's invasion of Ukraine'*, Energy briefing quarterly update – March 2022', Energy Efficiency Council, Melbourne.

47 Alternative Technology Association (ATA) 2018, *Household fuel choice in the National Electricity Market*, ATA, Melbourne, p.5.

2.3.2 Technical limitations

Heat pumps are a capable and versatile technology, however, like all technologies they have limitations and disadvantages. Some of these limitations can be managed through sensible equipment selection, design and installation; others are harder to overcome.

Temperature differential between heat source and sink

Heat pumps can provide heating and cooling services over a range of temperatures that are useful for residential, commercial and industrial purposes. However, the factor that has the greatest effect on heat pump efficiency and the coefficient of performance is the difference in temperature between the heat source and the heat sink. The lower the temperature difference, the higher the heat pump efficiency.[48]

This can particularly affect the performance of air-source heat pumps, as the temperature of the heat source – the ambient atmosphere – changes on a daily basis, and between times in the day.

Similarly, air-source heat pumps can 'ice-up' at low ambient temperatures – generally below 5°C. While heat pumps are designed with a defrost cycle to deal with this,[49] there can be impacts on performance, particularly if inappropriate equipment is selected. This is of relatively limited concern in Australia, as the lowest winter temperatures experienced outside of the alpine zone are within the capabilities of currently available heat pump units sold in Australia.

Temperature uplift limits

As required output temperatures increase, the difference in temperature between the heat source can increase beyond the useful working range of a heat pump. As the heat will typically be sourced from the air, ground or water, where temperatures are typically 5-25°C, high output temperatures will require a temperature uplift of 70°C or more.

Temperature uplift limitations mean that while heat pumps that supply heat above 100°C are available, they are not currently common. Heat pumps delivering heat above 160°C are in early stages of development. Innovations such as 'cascading' heat pumps, where the output of one heat pump feeds the input of another, can ameliorate this difficulty to some extent. However, at the time of writing temperature uplift limits the application of heat pumps in some industrial processes.[50]

While temperature considerations can limit heat pump use, ongoing R&D has continued to deliver improvements in product performance that have enhanced efficiency and applications.[51]

Integration and aesthetic limitations

Although heat pumps can replace gas or resistive electric equipment in many cases, there can be limitations to suitability of heat pump technology in specific applications:

- **Space and siting requirements:**
  Heat pump equipment can be bulky, and in the case of air-source heat pumps, a space with access to the large volumes of air is required. In commercial retrofit applications, existing plant rooms may not be able to accommodate heat pump equipment due to these requirements. These considerations may preclude a heat pump from being a drop-in replacement, and engineering solutions to integrate the heat pump can add to cost, potentially requiring significant system redesign.
- **Compatibility with existing process:**
  Although most low-temperature process heat could potentially be serviced by heat pumps, existing industrial processes may require redesign and infrastructure changes to take advantage of heat pump technology, which could add substantially to upfront costs.
- **Noise and aesthetics:**
  Heat pumps – particularly air-source heat pumps – can be a source of noise, and installation on the exterior of buildings can be visually intrusive. This can make their application in some situations, particularly for residential and commercial buildings, more difficult.

Integration limitations are most relevant when retrofitting appliances to existing buildings, as new buildings employing heat pump technology can be designed to seamlessly integrate heat pumps into the building plans. In addition, ongoing product development, as well as improving product standards for performance and noise, can help to reduce these concerns.

48 RACE for 2030 2021, _Decarbonising industrial process heating_, RACE for 2030, Canberra, p.55.

49 Mitsubishi Electric, _All you need to know about the defrost cycle this winter_, Mitsubishi Electric, Sydney.

50 RACE for 2030 2021, _Decarbonising industrial process heating_, RACE for 2030, Canberra, p.55.

51 Nowak, T. 2018, _Heat pumps: Integrating technologies to decarbonise heating and cooling_, European Copper Institute, Brussels.

2.4 The business case for heat pumps

The operating cost of heat pumps varies by the type of heat pump and the cost of electricity, and can be further influenced by climate and thermal requirements. However, a properly designed and installed heat pump will generally have lower running costs than competing technologies – see **Table 2**.

That means the financial case for an investment in a heat pump is largely determined by upfront costs.

The upfront cost of some heat pumps – notably RCACs – is relatively modest. However, other heat pumps have higher upfront costs relative to incumbent technologies, making it possible for heat pumps to save energy and emissions without delivering a financial benefit for the consumer.

Heat pumps will be the preferred choice when their benefits, on balance, outweigh the benefits of alternative technologies for providing thermal energy. Performance risks and implementation costs can also factor into the business case for heat pumps. The formula below describes the major variables that a business may take into account:

2.4.1 Upfront costs

Where heat pump technology is mature, and relevant skilled professionals and supply chains are well established, heat pumps can be highly cost competitive with alternative technologies; in Australia, RCACs are a notable example. However, if a particular heat pump technology is novel, design and installation professionals are unfamiliar with it, or supply chains are underdeveloped, upfront costs – the capital expenditure (CapEx) – can be high relative to competing technologies. HPHWS in residential buildings, heating in large commercial buildings and process heat in manufacturing and the food supply chain all fall into this category.

Because the running costs – the operational expenditure (OpEx) – of heat pumps are generally very competitive, reducing upfront costs – both in terms of capital costs and design and installation costs – is a key policy lever for driving the uptake of heat pumps.

$$\text{Heat pump CapEx} + \text{OpEx} + \text{Performance risks} + \text{Implementation costs} \leq \text{Incumbent or alternate CapEx} + \text{OpEx} + \text{Environmental costs}$$

Equation 1 Calculating the costs of heat pumps

2.4.2 Operating costs

Heat pump operating costs – the OpEx – are generally lower than other thermal systems based on typical market and system metrics. Simple examples, based on typical wholesale energy costs, are highlighted in **Table 2**:

Comparing thermal energy costs

	COP	Cost to deliver 1 GJ of heat
Natural Gas (@ $8/GJ)	0.95	$8.42
	0.85	$9.41
	0.7	$11.43
Natural Gas (@ $10/GJ)	0.95	$10.53
	0.85	$11.76
	0.7	$14.29
Natural Gas (@ $40/GJ)	0.95	$42.11
	0.85	$47.06
	0.7	$57.14
Natural Gas + carbon offsets (NG @ $8/GJ, ACCU @ $30/tonne)	0.95	$10.05
	0.85	$11.23
	0.7	$13.64
Hydrogen (@ $2/kg)	0.95	$17.54
Electric resistive (@ $60/MWh)	0.95	$17.54
Heat pump (@ $60/MWh)	3	$5.56
	5	$3.33
	10	$1.67
Heat pump (@ $120/MWh)	3	$11.11
	5	$6.67
	10	$3.33
Heat pump (@ $200/MWh)	3	$18.52
	5	$11.11
	10	$5.56

Table 2 Example thermal energy operating costs

2.4.3 Performance and implementation risks

In business settings in which the use of heat pumps is novel, performance and implementation risks are likely to be examined closely as part of the business case.

Performance risks relate to the ability of a heat pump to reliably provide the promised service. Implementation risks relate to the broader impact that heat pumps may have on a site or facility, such as implications for electrical interface, or uncertainty about maximum demand.

These risks may be **perceived**, resulting from a lack of familiarity with the specific technology under consideration, or **material**, arising from an application of the technology for which there is little prior experience. Both perceived and material risk can be l owered over time by:

- Supporting heat pump uptake within particular sectors;
- Building familiarity with the technology; and
- Encouraging rapid learning around heat pumps for performance and proper integration within a site or facility.

It can also be helpful to offset identified risks by highlighting the operational benefits of heat pumps, which can include:

- Reductions in maintenance costs;
- Improved safety resulting from the removal of gas appliances from facilities; and
- Reductions in combustion emissions other than greenhouse gas emissions, which results in improved health outcomes.

2.4.4 Incumbent technology costs

Incumbent technology has a range of obvious advantages. The upfront costs of incumbent technologies are well known, as skilled professionals and supply chains are well established. Operating costs can generally be projected with a reasonable degree of confidence. Although increased volatility in gas markets has introduced a higher degree of uncertainty.

Familiarity with equipment also makes the selection process simpler, as like-for-like replacement is understandably considered the safe option. In cases of unplanned failure, urgency and expediency to rectify the outage can also preclude consideration of alternate technology.

2.4.5 Environmental costs

Environmental costs are increasingly becoming material to any cost-benefit analysis. As net zero commitments and corporate social responsibility (CSR) pressures gain pace – from government, investors, supply chains and consumers – businesses may wish to demonstrate their commitment to emissions reduction. Reducing energy consumption – using heat pumps and other energy efficiency measures – and powering the remaining energy with renewables is a technically feasible pathway to deep, near-term emissions reductions for many businesses.

Other environmental costs could also bear on the analysis, particularly where combustion processes have impacts on the surrounding environment. These costs could include regulation of discharges of exhaust or effluent, noise or biodiversity concerns which could be ameliorated through electrification. These concerns are more likely to be material in larger industrial operations.

2.5 Other considerations

2.5.1 Refrigerants

Refrigerants are critical for the operation of heat pumps. Refrigerants are chemicals that convert from gas to liquid and back again as their temperature and pressure vary, moving energy from one part of the refrigeration cycle to another. Refrigerant choice is an important part of overall heat pump performance, in combination with overall system design and agreement between system design and intended application.

Historically, refrigerant blends have included chemical pollutants, contributing to both ozone layer depletion and climate change.[52] Driven by environmental and safety concerns, governments around the world are moving towards a phase-out of traditional refrigerants like hydrofluorocarbons (HFCs) in favour of alternatives with lower global warming potential (GWP) like natural refrigerants from hydrocarbons (HCs), hydrofluoroolefins (HFOs), carbon dioxide and other sources – see **Table 3**. Governments are doing this whilst also attempting to address efficiency, flammability, toxicity and the impacts of product breakdown.

The Montreal Protocol has been successful in reducing the impact of refrigerants on the ozone layer, while the Kigali Amendment to the Protocol, introduced on 1 January 2019, will help mitigate climate change by phasing down high GWP HFCs commonly used as refrigerants.[53]

The total CO_2e value of refrigerants used in Australia is expected to drop from around 7.44 million tonnes in 2019 to around 4.6 million tonnes in 2030, which is a drop of more than 40%.[54]

Heat pumps, Alternative refrigerants	Substance	GWP	Compositon	Replacement for
Natural refrigerants	R290 (propane)	3	–	R134a R407A R410A
	R717 (ammonia)	0	–	R134a R407A R410A
	R744 (CO_2)	1	–	R134a R407A R410A
Synthetic HFC-HFO blends	R452B R454B R455B R513B	698 466 148 631	R32/125/1234yf R32/1234yf R32/1234yf/CO_2 R1234yf/134a	R410A R410A R410A R134a
Synthetic HFOs	R1234ze	7	–	R134a R407A R407A
Synthetic HFCs	R32	675	–	R134a R407A R410A

Table 3 Alternative refrigerants for heat pumps

Source: Alfa Laval 2021.

52 Department of Agriculture, Water and the Environment 2021, *Refrigeration and airconditioning – Consumers*, Australian Government, Canberra.

53 United Nations Environment Programme (UNEP) n.d., *Kigali cooling efficiency programme*, UNEP, Paris.

54 Brodribb, P., and McCann, M. 2020, *Cold Hard Facts 2020*, Department of Agriculture, Water and the Environment, Canberra.

Risk of refrigerant leakage

Opportunities for emissions reduction from heat pump deployment come with a concurrent risk of increases in emissions through leakage of refrigerants to the atmosphere. In this report, refrigerant risk is considered to be managed through existing government policy and programs.

Quantitative evaluation of the impact of refrigerant leakage is out of scope for this report, however, efforts to minimise refrigerant risk should be front of mind for policymakers. While the shift towards low GWP refrigerants is underway, policies and programs that look to accelerate deployment of heat pumps should work in tandem with efforts to encourage adoption of low or zero GWP refrigerants.

As part of the Victorian Gas Substitution Roadmap, consultants were commissioned to model the emissions associated with increased heat pump usage through the Roadmap. The report concluded that the installation of 9.5 million heat pumps in Victoria would lead to refrigerant-related emissions of 11.3 Mt CO_2e over three decades (or approximately 0.39 Mt CO_2e per annum), which could be reduced to 7.85 Mt CO_2e through improved controls and compliance.[55]

This report has not quantitatively compared additional refrigerant-related emissions to the emissions reduction available through heat pump technology. However, the magnitude of potential abatement illustrated by the *Model* developed for this report suggests that the additional refrigerant-related emissions would be significantly outweighed by the reduction in emissions due to substituting gas and resistive electric heating with heat pump technology. Further technical work would be required to precisely quantify the Australia-wide refrigerant-related emissions associated with heat pump deployment, and hence the net abatement that heat pumps could deliver once refrigerant-related emissions are taken into account.

2.5.2 Fuels

Heating and cooling services use substantial amounts of energy in Australia. This energy is derived from a range of fuels either directly through combustion, or indirectly through electricity use.

Coal, oil, gas, electricity and renewables are currently used for space and water heating and cooling in Australian buildings, and manufacturing and agriculture sites. Wood is used for space heating in residential settings and in processing of paper and pulp. Bagasse is used in the sugar industry.

Replacing inefficient resistive electric appliances with heat pumps reduces emissions through reduced consumption of grid supplied electricity. Where appliances that use other fuels are replaced with a heat pump, emissions savings vary depending on the emissions intensity of the fuel being replaced relative to grid supplied electricity.

Pairing electricity generated onsite by solar PV with a heat pump generally maximises savings in both emissions and cost, relative to grid supplied electricity.

Green hydrogen, while currently at a low stage of technological maturity and not widely used, is another alternative fuel that is central to the Australian Government's net zero plan.[56] Organisations such as the Australian Renewable Energy Agency (ARENA) are currently undertaking research trials. In the future, hydrogen could be used to fuel some processes that are currently powered by fossil fuels.

Fuel penetration by geographic region

The availability and application of these fuels varies across the country – see **Figure 4**. Natural gas is the dominant fuel for space heating in residential and commercial buildings in Victoria and the Australian Capital Territory, where gas connections to homes are common and winter temperatures are low.[57] Elsewhere in the country, electricity is the dominant fuel for space heating. However, wood is commonly used in Tasmania due to its consistent availability, relative affordability, and low winter temperatures.[58]

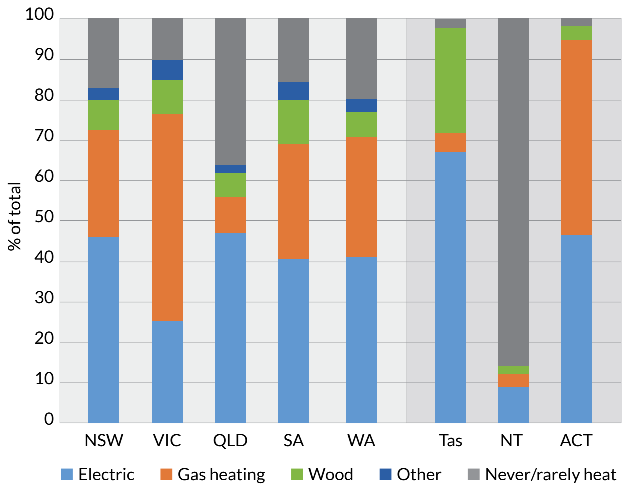
Reverse cycle air-conditioning is now widely deployed across Australia. However, feedback from consultation has suggested that while reverse cycle air conditioners are the norm for cooling, some householders are unaware of the potential benefits of using the RCAC as a source of low-cost heating.

55 Brodribb, P. and Dewerson, G. 2022, *Climate risk of heat pumps*, Expert Group, Melbourne, P.29.

56 Department of Industry, Science, Energy and Resources (DISER) 2021, *Australia's long term emissions reduction plan*, Commonwealth of Australia, Canberra, p. 47.

57 Equipment Energy Efficiency (E3) 2021, *Residential space heaters in Australia & New Zealand*, Australian, State and Territory and New Zealand Governments, Canberra and Wellington, p. 26.

58 Ibid, pp. 26-27.



Source: for five large states obtained from 2020 data (BIS Oxford Economics, 2020) and from ABS, 2014, for Tas, NT and ACT.

Figure 4 Household main source of energy used for heating by jurisdiction

Source: Equipment Energy Efficiency (E3) 2021, p. 27.

Gas is the dominant supplier of heat in manufacturing sites, with diesel oil being much more common in agricultural settings.

Grid electricity is available throughout urban areas and in most regional areas. In remote areas, electricity is delivered by several microgrids, with many regional and remote areas having diesel and liquified petroleum gas (LPG) providing the main source of electricity generation.

Greenhouse gas intensity of electricity generation

An important factor in the ability of heat pump technology to reduce emissions is the relative emissions intensity of the electricity used to power heat pumps, compared to the emissions intensity of other fuels used for heating and cooling services. Since June 2008, the emissions intensity of the National Electricity Market (NEM) has reduced by 30%.[59] As further renewable energy is brought online, the emissions intensity of grid electricity will fall further. This means that the emissions savings that can be achieved by switching fossil-fuel based heating processes to heat pumps will grow ever greater.

This report uses two scenarios from the Australian Energy Market Operator's 2020 Integrated System Plan to underpin its modelling. Under those scenarios, emissions intensity of the NEM is projected to fall considerably by the middle of the 2030s – see **Figure 5**. AEMO's 2022 Integrated System Plan suggests even more substantial reductions in emissions intensity, with all proposed scenarios envisioning more than 95% of electricity in the NEM to come from renewable sources before 2050.[60]

This highlights the substantial, and increasing, opportunities to reduce greenhouse gas emissions through the deployment of heat pumps, and the important role that they can play in achieving net zero emissions by 2050.

National Electricity Market emissions intensity

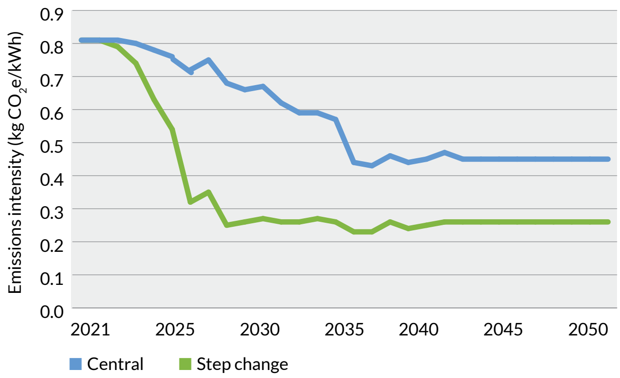


Figure 5 Projected greenhouse gas emissions intensity in the National Electricity Market

Source: The *Heat Pump Energy and Emissions Savings Model*, based on AEMO ISP 2020.

2.5.3 Climate zones

In Australia, requirements for heating and cooling in buildings varies significantly by climate zone. The National Construction Code (NCC) defines eight climate zones with varying heating and cooling requirements – see **Figure 6**. Climate zones one to three, found in the north of the country and the north-eastern coast, have hot summers and mild to warm winters. Cooling is the primary energy requirement, and little space heating should be required in thermally efficient buildings. In practice, however, many existing buildings in these regions are thermally inefficient, leading some occupants to rely on electric resistive heating, at significant cost.

59 Saddler, H. 2021, *National emissions energy audit report – October 2021*, The Australia Institute, Canberra, p.10.

60 Australian Energy Market Operator 2022, *2022 integrated system plan*, AEMO, Melbourne, p.45.

Climate zones four and five tend to have warm summers and cool winters, meaning both cooling in summer and heating in winter are required in most buildings. Climate zones six to eight have colder winters, with climate zone eight having the coldest winters in the country. Heating is required in winter in these climate zones, and cooling may be used in summer. As the climate changes, demand for cooling services may increase.

Hot water is used in all climate zones, particularly in residential settings for showers and hot tap water.

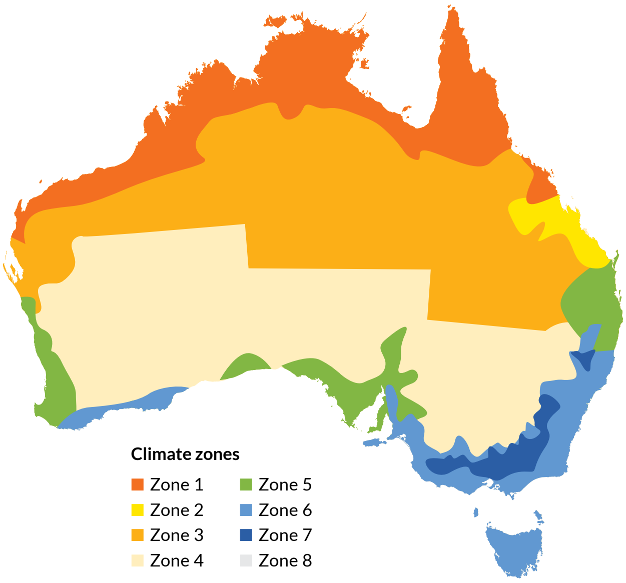


Figure 6 The National Construction Code (NCC) defines climate zones of Australia

Source: ABCB 2019.

Granular analysis of the role of heat pumps by climate zone is out of scope for this report. However, it is important to note that heating and cooling requirements vary across these zones, as does the relevance of heat pump applications. For example, heat pumps for space heating present a significant opportunity to decarbonise heating in climate zones six through eight, but to a lesser extent for climate zones one through three.

In some climate zones, low temperatures require careful equipment selection. The new climate zone based RCAC label, which is currently being phased in, offers a mechanism for this – see **Figure 7**.

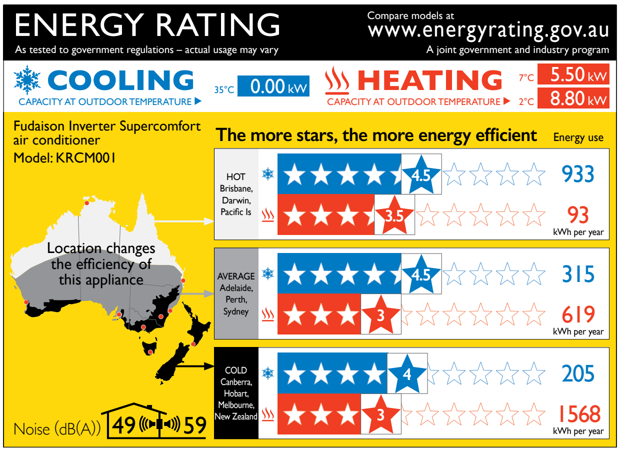


Figure 7 The new Zoned Energy Rating Label (ZERL) being phased in for RCACs across Australia

Source: Energy Rating 2020.

Heat pumps work in all Australian climates

Heat pumps are used in many cold climates around the world. While ground-source heat pumps are most effective in very cold climates, air-source heat pumps can still be used in cold climates with temperatures down to -25°C.[61] Although air-source heat pump efficiency can diminish in lower temperatures, the COP of heat pumps still outperforms other heating technologies in cold climates. **Figure 8** shows that even at the lowest temperatures likely to be experienced in Australia (-10°C), an air-source HPHWS still can have a COP of more than two.

COP vs. Ambient Temperature (°C)

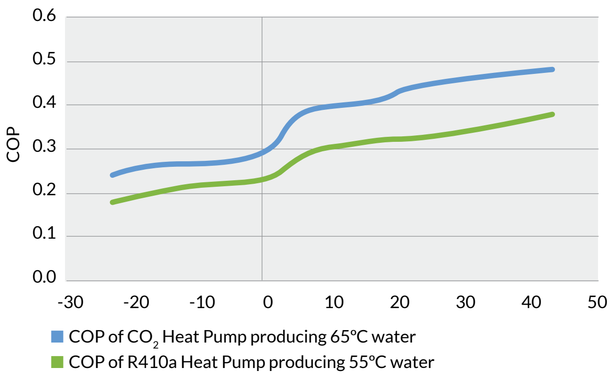


Figure 8 Efficiency of HPHWS in different temperatures

Source: Bannister, n.d.

61 Manitoba Hydro n.d., *Cold climate air source heat pumps, Manitoba Hydro, Winnipeg, Canada*; Nadel, S. 2020, *Programs to electrify space heating in homes and buildings*, ACEEE, Washington, DC.

3

Scope, methodology and whole of economy results

Summary

- The **analysis in this report** is based on a survey of relevant literature, expert consultation and development of a quantitative impact model of energy and emissions savings from heat pump deployment.
- **Four hypothetical adoption scenarios are modelled** across residential, commercial and industrial sectors, showing that the greatest energy and emissions savings are realised through early adoption.
- Under the hypothetical scenarios, ambitious, early deployment of heat pump technology **could save up to 14,391 PJ of energy and 746 Mt CO_2e** of greenhouse gas emissions nationally by 2050.

3.1 Scope

Heat pumps have the potential to be a low-cost source of abatement. However, there is a lack of evidence about the potential abatement available in Australia, and how this opportunity could be unlocked in residential, commercial, and industrial settings.

To begin filling this evidence gap, the Department of Climate Change, Energy, the Environment and Water commissioned the EEC and A2EP to undertake research and analysis of the interaction between heat pump adoption, economic sectors, public policy and regulation, and to provide guidance on the role of heat pumps in reducing energy and emissions. The research is intended to build an evidence base for the role, application and potential impact of heat pumps for providing low-cost abatement in Australian buildings and industrial processes, and identify opportunities and gaps to inform policy and programs, efforts in research, development and demonstration, standards and workforce development to realise the abatement opportunity of heat pumps, as well as investment opportunities in low-emissions technologies.

To achieve these objectives, this report:

- Identifies opportunities for heat pump technologies to realise energy and emissions savings in Australian buildings and industry through literature analysis and expert opinion;
- Quantifies the size of potential energy and emissions savings from heat pump technologies through the development of an impact model;
- Identifies actions to accelerate heat pump deployment;
- Identifies challenges and barriers to heat pump adoption;
- Identifies policies and programs that can support heat pump deployment; and
- Identifies investment opportunities in low emissions heat pump technologies.

3.2 Methodology

The development of this report involved a mixed methodology of qualitative and quantitative research, including:

1. Desktop research and literature review;
2. Consultation; and
3. Development of the *Heat Pump Energy and Emissions Savings Model*.

3.2.1 Desktop research and literature review

A comprehensive review of literature concerning applications of heat pumps across buildings and industry in Australia and around the world was undertaken to inform both the consultation with industry and the *Model*. A comprehensive list of resources can be found in the References.

Limitations

Heat pump performance, deployment and potential for energy and emissions savings are very dependent on individual operating circumstances. Limited published information exists on real-world performance of heat pump technology in Australia, and so this report has relied extensively on qualitative data, including feedback from industry experts.

3.2.2 Consultation

Extensive consultation was undertaken in support of developing this report, including:

- A public forum;
- Interviews with industry representatives from Australia and overseas;
- Interviews with researchers, organisations, and other experts on heat pumps from Australia and overseas; and
- Interviews with government representatives at the federal and jurisdictional level in Australia.

The public forum took place at the commencement of the project to get early feedback on relevant literature and data points for the *Model*, as well as to gauge industry perspectives on the key barriers and opportunities related to the adoption of heat pumps in Australia.

Aggregated findings from the consultation are included in Appendix 3, and interviewees are recognised in the Acknowledgements.

3.2.3 *Heat Pump Energy and Emissions Savings Model*

Model design

The *Model* was developed by A2EP, with the support of the EEC and key industry experts. The *Model* enables exploration of how the replacement of existing low and medium-temperature heat technologies – up to 150°C – with heat pumps will affect energy and emissions outcomes over time.

The *Model* focuses on:

- Residential space heating;
- Residential water heating;
- Space heating and cooling in commercial buildings; and
- Heat-related services in manufacturing.

The *Model* estimates how much thermal energy is required for activities or services in each sector. As there is insufficient data at the sector level, overall system efficiency for each energy source has been applied. This incorporates consideration of real-world factors that influence efficiency of thermal energy systems, based on a review of a range of studies and past experience.

By matching sector energy use in thermal systems to the estimated efficiency of existing thermal systems, it is possible to derive an estimate of the required thermal energy service. Applying heat pump COPs to this amount enables a comparison of the energy input needed for heat pumps with the baseline energy estimates, i.e. the energy input needed for non-heat pump heat-related services.

The *Model* utilises the best available data at the time of development, and has been designed to be updated as improved data becomes available. For example, the *Model* has the flexibility to allow estimations and assumptions to be adjusted to explore:

- Sensitivity studies related to rates of heat pump adoption;
- Trends in emission intensity of electricity and other energy sources; and
- Efficiencies of delivering heat-related services.

The *Model* also allows energy and emissions outcomes of different rates of uptake of heat pumps to be explored, which can inform policy development. The *Model* does not explore the costs, and modelling the economic costs of deployment pathways is beyond the scope of this report.

For further information on how the *Model* works, see Appendix 2 and the worksheets in the *Model*; this includes:

- Understanding the worksheets;
- Interpreting the scenarios;
- Strengths and limitations; and
- A data dictionary providing further information on each of the variables contained in the *Model*.

Model scenarios

The *Model* is designed to explore the potential energy and emissions savings that could be achieved under different scenarios of market intervention and technology uptake from now to 2050.

The outputs are presented for four different scenarios of heat pump adoption, combined with electricity emissions intensities from two scenarios in AEMO's 2020 Integrated System Plan.

The adoption scenarios are:

- **Late adoption 2040-2050:** rapid uptake delayed until 2040, with 100% penetration achieved by 2050;
- **Linear to net zero 2050:** 3.3% increase in annual uptake of new heat pump opportunities to 2050;
- **Linear to net zero 2050 with extra efficiency:** recognising that the installation of heat pumps in new areas of application can be accompanied by complementary measures of system redesigns that improve energy efficiency, this scenario adds an extra 2% energy efficiency improvement in addition to the baseline 2.1% annual improvement; and
- **Supercharged deployment in ten years:** hypothetical 10% per annum take up from 2020 achieving 100% penetration by 2030.

Electricity emissions intensity projections are sourced from the AEMO 2020 Integrated System Plan. The AEMO scenarios provided in the *M odel* are:

- **Central:** reflecting market forces and current federal and state government policies; and
- **Step Change:** where both consumer-led and technology-led transitions occur in the midst of aggressive global decarbonisation.[62]

Future baseline projections include allowance for:

- **Sector and economy growth:** set to 2.6% per annum; and
- **Energy efficiency improvement:** set to 2.1% per annum.

Based on the requirements of the Client, these growth rates are based on:

- Projections of GDP growth in the 2021 *Intergenerational report*;[63] and
- Average improvements in energy efficiency observed between 2010 and 2019.[64]

A further scenario has been modelled for the industrial sector – *slow industrial growth*. In this scenario, the effects of lower growth and lower efficiency improvement are explored. While the deployment of commercially-ready heat pumps in residential and commercial settings could reasonably be expected to be reflective of broader economy-wide trends, heat pump deployment in industrial settings is typically more bespoke and could be slowed by limitations on the availability of technology, skills or capital. A summary of the parameter settings used in differed *Model* scenarios is provided at **Table 4**.

Factor	Late adoption	Linear to net zero 2050	Linear to net zero 2050 + extra efficiency	Supercharged deployment	Slow industrial growth
Sector growth (% p.a.)	2.6	2.6	2.6	2.6	0.5
Efficiency improvement (% p.a.)	2.1	2.1	4.1	2.1	1
Heat pump penetration	10% per year from 2040	3.33%	3.33%	10% per year from 2020	2.5%

Table 4 *Model* parameter settings

62 Australian Energy Market Operator (AEMO) 2020, *2020 Integrated System Plan*, AEMO, Melbourne, p. 11.

63 Department of the Treasury 2021, *2021 Intergenerational Report*, Australian Government, Canberra, p.1.

64 International Energy Agency (IEA) 2020, *Energy Efficiency 2020*, IEA, Paris, p.14.

Achieving the adoption scenarios

The *Model* relies on hypothetical adoption scenarios that are modelled against business-as-usual. These scenarios have been constructed to explore the effect of speed of heat pump adoption on energy and emissions savings.

It is important to emphasise that these scenarios are unlikely to track actual deployment progress; rather, they are tools to investigate sensitivity of energy and emissions savings and estimate the potential size of available abatement.

The scenarios have important limitations. For example, while each scenario ends with 100% heat pump deployment in the modelled sectors, there may be valid technical factors that prevent this being achieved. Similarly, in the absence of broad-based, nationally consistent regulation phasing out legacy technologies and encouraging electrification, it is likely that there will be adoption 'laggards' that will not take up new technologies.

Furthermore, future changes in technology, economics and policy settings could significantly affect rates of deployment. In particular, should hydrogen become technologically and commercially mature, this may compete with heat pump technology for some applications and affect assumptions about energy and emissions savings.

The hypothetical modelling scenarios are not based on particular policies or programs to accelerate heat pump adoption. While this report does not endorse any particular policy approach to achieve the adoption scenarios, the following list is an indication of an *initial* suite of policy measures that would be necessary to catalyse adoption rates consistent with the modelling scenarios. Actual achievement of scenario endpoints would be likely to require further policy measures, including regulation, based on the market response to initial interventions.

- Late adoption 2040-2050:
  - Support for targeted R&D, particularly for industrial applications; and
  - Limited awareness-raising activities.
- Linear to net zero 2050:
  - Greater support for targeted R&D, particularly for industrial applications;
  - Ongoing awareness-raising activities; and
  - National financial support for deployment to low-income households.
- Linear to net zero 2050 with extra efficiency:
  - Support for ongoing targeted R&D, piloting and knowledge-sharing in industrial and commercial settings;
  - Ongoing awareness-raising and workforce skills development programs;
  - Iterative, increasing ambition of building codes;
  - Establishing and improving product energy efficiency standards – such as for those covered by the E3 program – and the introduction and gradual increasing of minimum energy performance standards for thermal services equipment; and
  - National financial support for deployment and integration into low-income households.
- Supercharged deployment in ten years:
  - Substantial support for rapid R&D, piloting and knowledge-sharing in industrial and commercial settings;
  - Stringent minimum energy and greenhouse performance standards for thermal services equipment that phase out new gas and resistive electric equipment by the middle of the decade;
  - Step-change increase in ambition of building codes including a phase-out of gas for residential purposes;
  - National financial support for deployment and integration into households and businesses; and
  - Significant awareness-raising and workforce skills development programs.

More information regarding potential policy measures can be found in *Section 4*.

Model limitations

This *Model* represents a step forward in the analysis of the possible energy and emissions savings associated with the deployment of heat pumps in the context of a decarbonising electricity grid. It is well-suited to conducting sensitivity studies and supporting the setting of policy priorities by estimating the relative energy and emissions abatement opportunity from different penetrations of heat pump conversions for heat-related services.

However, the *Model* has inherent limitations, most notably data availability and methodologies for disaggregating energy usage between different services.

Greater investment in data capture and analysis would enhance the operation of the *Model*. The design of the *Model* allows for the addition of improved data and future analysis without significant additional development.

It is possible to use the commercial or industrial worksheets to explore any specific energy consuming activity where heat pumps have potential application. The base energy consumption data can be changed to apply to the desired activity, then technology efficiency variables, rate of change, etc., can be specified to support more granular modelling.

Refrigerant leakage

Assessing the impact of potential refrigerant leakage – leading to lower net abatement from the deployment of heat pumps – has not been quantitatively assessed in the *Model* and is not within the scope of this report. Refrigerant risk varies considerably based on the specific refrigerant risks, and the *Model* does not explore the impacts of individual heat pumps and/or refrigerant types.

Grid constraints

The *Model* does not (and cannot) take into account any limitations placed on heat pump deployment by local electricity grid circumstances. Larger industrial energy users may face barriers to adoption of heat pump technology through insufficient local capacity being available. Similarly, the *Model* does not assess whether deployment of heat pump technology would have a material impact on peak demand, either in summer (through additional air-conditioning load) or winter (through substitution of gas heating for electrically powered heat pumps). These considerations – while important – are outside the scope of the *Model* and this report.

Behavioural and rebound effects

The *Model* does not consider any potential effects that heat pump deployment may have on user behaviour that could induce a 'rebound effect' or other phenomena that could reduce the modelled energy and emissions savings. The *Model* is based on current energy usage data and estimates the potential energy and emissions savings resulting from substituting usage of resistive electric and natural gas and other fossil fuels with electrically driven heat pumps. It is possible that end-users could increase their heating energy use after installation due to a reduction the expected cost of running heating equipment, or that consumers installing a reverse-cycle air-conditioner could use the system to cool their house in the summer as well (instead of no cooling, or running an evaporative cooling system). These actions could have the effect of reducing the total energy and emissions savings resulting from installing heat pump technology, but the extent to which they would affect the energy and emissions savings modelled for this report are not clear.

Potential for enhancing the *Model*

There are some areas that were outside the scope of this report, but present rich opportunities for future enhancements of the *Model*.

The *Model* is currently based on average annual electricity emissions intensities, which assumes that every unit of energy saved by a heat pump reduces emissions by an identical amount across the day or across seasons.

However, an in-depth consideration of the role of demand response and load-shifting to take advantage of the flexibility of heat pumps and thermal storage would be likely to demonstrate opportunities to reduce emissions more rapidly. As noted in *Section 2*, a heat pump can be programmed to run during the middle of the day – when solar PV generation is at its peak – and to avoid running during periods of the day when emissions-intensive generation is used – such as during morning and evening peak times.

Demand-responsive or load-shifted heat pump deployment, coupled to effective thermal storage – such as a hot water tank – could lead to very high levels of abatement, and merits further exploration.

Similarly, the *Model* makes a relatively cursory examination of other actions that could substantially increase the energy savings alongside heat pump deployment. Areas that could merit more granular modelling and analysis include:

- Changes to processes that could occur during heat pump installation – such as insulation of piping or reduction of process heat requirements;
- The interaction between energy efficiency activities – such as a reduction in space cooling requirements that might occur when an inefficient boiler that generates significant waste heat is replaced by a heat pump; or
- The installation of heat pump equipment in a residential setting that is accompanied by renovation works that improve building thermal performance.

Understanding the opportunity

Heat pumps are already used in many applications. This research identifies the heat services that are currently not being met by the use of heat pumps, to quantify the energy savings available from transitioning to heat pumps, and the associated reduction in energy and emissions.

Determining the amount of energy used to meet low temperature thermal needs suitable for heat pumps is not a straightforward task. Australia's energy statistics are not gathered at the level of detail required so this report is based on a subset of the economy-wide energy statistics, specifically the *Australian Energy Statistics 2020 – Table A2* repurposed below in **Table 5**:

	Black coal	Brown coal	Met. coke	Coal by-products	Natural gas	Crude oil and ORF	LPG	Refined products	Liquid/gas biofuels	Biomass – wood	Biomass – bagasse	Total electricity	Solar hotwater	Total	Energy in HP model
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
Total final energy consumption	**100.5**	**0.5**	**8.8**	**0.7**	**979.9**	**1.7**	**54.3**	**2,220.6**	**8.8**	**73.9**	**77.0**	**846.1**	**17.5**	**4,390.3**	**643.0**
Agriculture					1.3		1.9	92.0				7.8		103.1	Not included
Mining	4.2		1.2	0.0	392.3	1.0	1.7	263.0	0.0	0.0	0.0	149.0		812.4	
Food, beverages, textiles	7.3			0.0	38.0	0.7	1.0	4.5	0.8	1.9	77.0	22.4		153.5	359
Wood, paper and printing	2.7			0.0	13.1		0.2	2.5	0.8	18.4		16.5	0.0	54.2	
Chemical	6.4		0.2	0.0	113.5		10.2	41.7	0.2	0.5	0.0	14.1		186.8	
Iron and steel	0.4		4.3	0.0	9.2		0.0	0.5				12.5		27.0	
Non-ferrous metals	61.3		3.0	0.3	123.3		0.0	31.4	0.0	1.9		112.0		333.1	
Other industry	18.1	0.0	0.1	0.4	53.6		5.4	3.8	0.3	3.5		21.3		106.6	
Water and waste		0.5			1.2		0.0	1.3	0.4	0.0		13.1		16.5	Not included in heat pump modelling
Construction				0.0	2.8		0.2	20.4	0.0			0.9		24.3	
Road transport					3.5		15.8	1,205.4	6.3			0.1		1,231.0	
Rail transport	0.0				0.1		0.0	52.0	0.0			11.7		63.8	
Air transport								349.4						349.4	
Water transport	0.0				0.2			66.6						66.8	
Other transport, services and storage	0.0				0.5		0.3	8.4	0.0			10.0	0.0	19.1	
Commercial and services	0.0			0.0	58.6		1.4	28.4	0.0	0.2		243.6	0.5	332.5	76
Residential	0.0			0.0	168.8		16.0			47.6		211.4	17.0	460.9	208
Lubes, bitumen, solvents								49.3						49.3	

Table 5 Australian energy supply and consumption, 2018-19, energy units: Table A2, showing the estimate of energy used for low temperature heating and included in the heat pump modelling of energy and emissions reductions

Source: DISER 2020.

3.2.4 Interpreting the *Model* results

The *Model* represents a contribution to understanding the size of the opportunity for energy and emissions savings that heat pumps could bring to Australia. However, the *Model* produces results at an aggregate level that are illustrative of the size of the opportunity -it does not (and cannot) predict what the actual abatement or energy use reduction will be as heat pumps are deployed in Australia.

The *Model* predicts the aggregate opportunity

The *Model* estimates the gross size of the opportunity to reduce energy use and emissions by substituting heat pump technology for other types of heating. The estimates of the size of the opportunity are based on national data of energy usage and considers a generalised technology substitution. The *Model* does not consider individualised situations and *Model* users should understand that actual heat pump deployment may or may not approximate the scenarios modelled in this report.

The *Model* explores sensitivity through hypothetical scenarios

The *Model* uses a set of hypothetical deployment scenarios to understand how key parameters of heat pump adoption will influence the size of potential energy and emissions savings The modelled scenarios do not correlate with actual heat pump deployment, and may or may not be achievable in real-world conditions. However, they are effective tools for exploring how different deployment rates influence the amount of abatement and energy use reductions

Uncertainty varies by sector

Although the *Model* presents results for three separate sectors (residential, commercial and industrial), the confidence associated with the modelled energy and emissions savings in each sector varies. For example, in the residential sector, the applications for heat pumps are relatively mature and well understood – being space heating and water heating using standard consumer appliances. This suggests that the estimates of the potential energy and emissions savings associated with deployment of heat pumps to the residential sector can be regarded with a relatively high degree of confidence.

In the industrial sector, heat pump deployment is subject to a greater number of uncertainties – including the suitability of available systems for individual applications, the ability of industry to effectively integrate heat pump technology into existing processes, access to sufficiently large sources of ambient heat and wider economic factors including access to expertise, skills and capital. This means that the amount of energy and emissions savings in the industrial sector could be less than modelled.

However, modelled results in the industrial sector also are derived from a relatively conservative assessment of the amount of heat that could be substituted with heat pump technology. As technology improves over time – and new products become commercially available – the amount of heat that could be substituted with heat pump technology could also increase towards 2050. This means that the relative confidence associated with energy and emissions savings in the industrial sector is lower than those associated with residential applications. (Modelled emissions and energy savings in the commercial buildings sector is likely to have a level of confidence between residential and industrial sectors).

Ultimately, users of this report should be aware that the estimates of energy and emissions savings presented here are attempts to estimate the potential magnitude of energy savings and emissions abatements that deployment of heat pump technology could catalyse – but do not represent exact estimates of the deployment that will occur under any particular heat pump deployment scenario.

3.3 Results from the *Model*

3.3.1 Whole of economy energy and emissions savings

Using the settings illustrated above provides whole-of-economy energy and emissions savings projections to 2050 shown in **Table 6**:

Heat pump penetration scenario	Cumulative energy savings to 2050 (PJ)	Cumulative greenhouse gas savings to 2050 compared to baseline (Mt CO_2e)	
		AEMO 'Central'	AEMO 'Step change'
Late adoption 2040-2050	3,235	163	169
Linear to net zero 2050	8,845	441	460
Linear to net zero 2050 + extra efficiency	11,933	660	618
Supercharged deployment in 10 years (10% p.a.)	14,391	713	746

Table 6 Results from the *Heat Pump Energy and Emissions Savings Model* – energy and emissions savings projections from heat pump penetration scenarios

Sector-specific projections are provided in Sections 5, 6 and 7.

The *Model* confirms that the greatest energy and emissions savings are achieved through early adoption of heat pump technology – the supercharged deployment scenario – with up to 746 MtCO_2e in cumulative emissions reductions and 14,391 PJ of energy savings available when compared to the business-as-usual baseline – see **Figure 9** and **Figure 10**. While this represents achievement of a highly ambitious scenario that is unlikely without extraordinary policy interventions, it illustrates the significant advantage of early action to encourage deployment of heat pumps.

Cumulative net energy reduction by sector

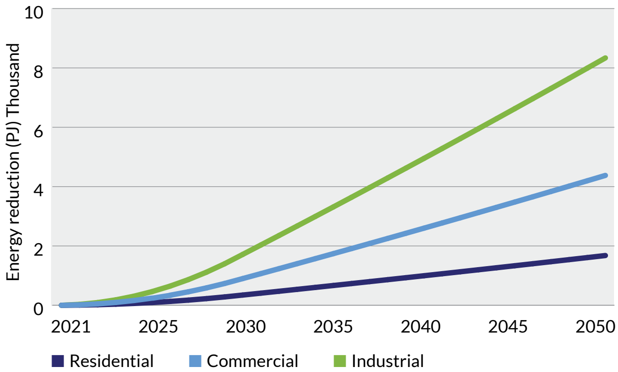


Figure 9 Cumulative net energy reduction by sector under the supercharged deployment scenario

Cumulative net emissions abatement by sector

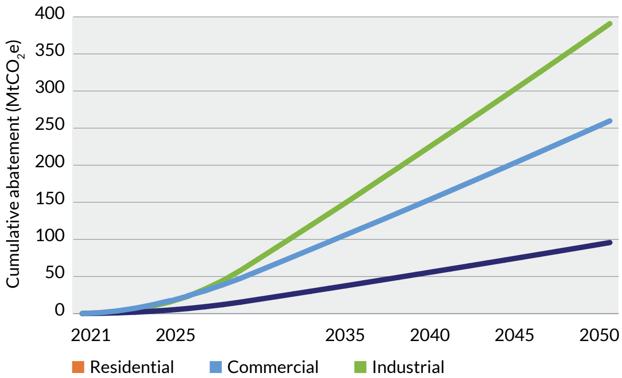


Figure 10 Cumulative net emissions abatement by sector under the supercharged deployment (AEMO 'Step Change') scenario

Annual energy savings under the supercharged deployment scenario are shown in **Figure 11**, rising rapidly to 545 PJ in 2030, or 19.8% of the total non-transport energy from the baseline year of 2018-2019.

Heat pump net annual energy reduction by sector

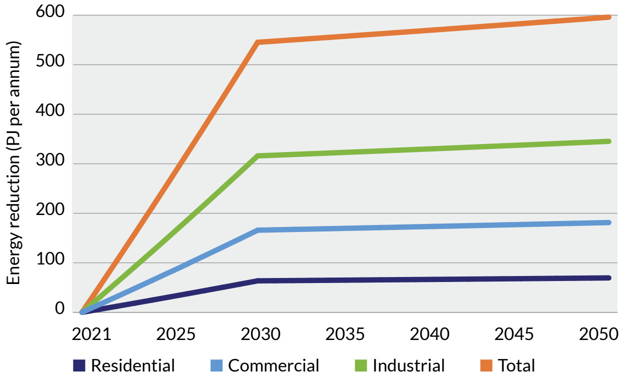


Figure 11 Annual energy savings by sector due to heat pumps under the supercharged deployment scenario

The *Model* demonstrates that the potential energy and emissions savings are substantial under any scenario, with the AEMO 'Central' and 'Step change' scenarios making a limited difference to the emissions abatement potential – see **Figure 12**. In particular, the *Model* illustrates that there are significant energy and emissions savings available by switching low temperature systems to heat pumps, and that the greatest reduction in energy and emissions is achieved through early deployment of heat pump technology.

Emissions savings to 2050

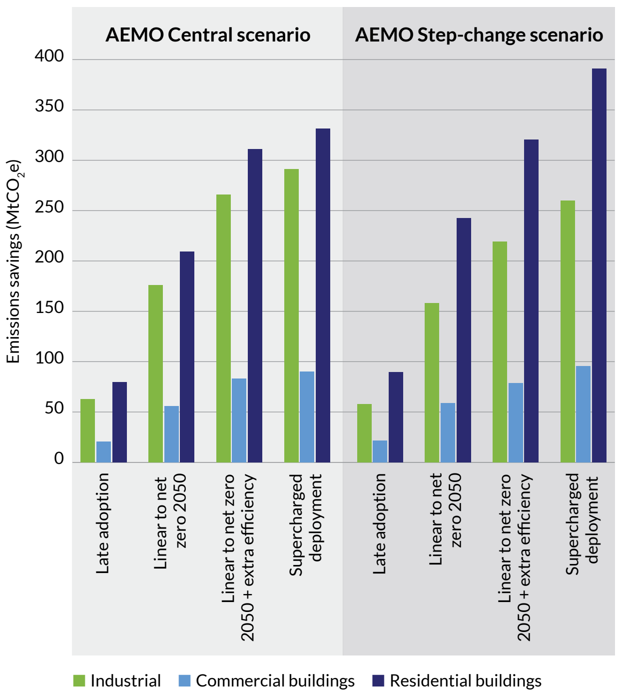


Figure 12 Cumulative emissions savings to 2050 by adoption scenario

Given the projected transition of the electricity grid to high penetrations of renewable energy, it is important to consider the impact of scaling up heat pump deployment at times of high and low demand, and variable renewable energy output.

Replacing appliances and equipment currently powered by other fuels, such as gas, would create additional electricity usage. However, the increase in electricity consumption from fuel switching is much smaller than the overall energy reductions across all fuels, because of the significant difference in COP between non-heat pump and heat pump technologies. For example, in the industrial sector, under the supercharged deployment scenario, energy savings of 349 PJ are achieved in 2030, while electricity consumption increases by 33 PJ, resulting in a net decrease in energy usage of 316 PJ.

The greatest potential energy and emissions savings are in the industrial sector, followed by the residential and then commercial buildings sectors – see **Figure 13**. While there is potential for cost-effective abatement in other sectors, the opportunities are not as large, and were therefore not in scope for the modelling commissioned for this report. Desktop research and interviews conducted for this report confirms this view.

Energy Savings to 2050

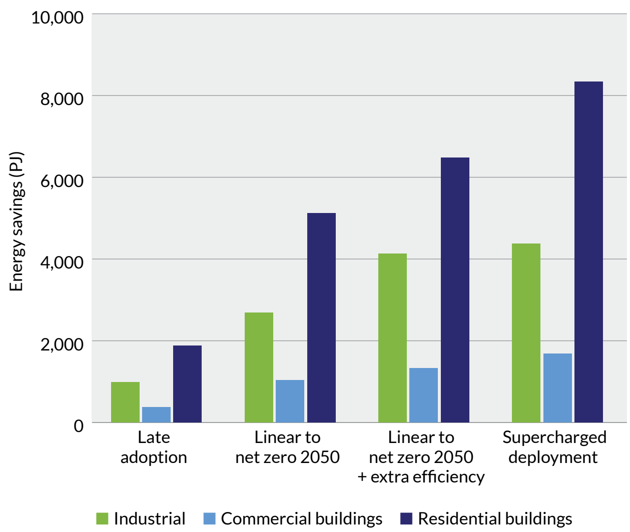


Figure 13 Cumulative energy savings to 2050 by adoption scenario

4

Unlocking the opportunity: pathways and policies to support deployment

Summary

- Heat pump technology is at **varying levels of adoption and commercial maturity**.
- Heat pump technology **can deliver abatement**, but a range of barriers – including market failures – exist that can prevent widespread deployment.
- **Policy and program measures can overcome these barriers**, including R&D, pilot and demonstration projects, regulation, standards and financial incentives.
- Prioritisation of policy measures should **consider the scale** of the available abatement opportunity, as well as the timeframe for realising abatement.

As demonstrated in *Section 3*, wide scale deployment of heat pump technology has the potential to deliver significant energy savings and emissions abatement. Domestic and international experience – discussed in Sections *5*, *6* and *7* – illustrates that there are many ways that heat pumps could be further used to improve efficiency and productivity, reduce energy usage and contribute to Australia's net zero emissions goals.

The underlying technology of heat pumps is well understood, and they have achieved a high level of technological maturity and mass deployment in several applications such as refrigeration and residential space cooling. However, there are other applications for heat pumps that are at earlier stages of adoption, and the benefits of heat pump technology will be unlocked only if the adoption of heat pumps moves further along the technology diffusion curve – see **Figure 14**.

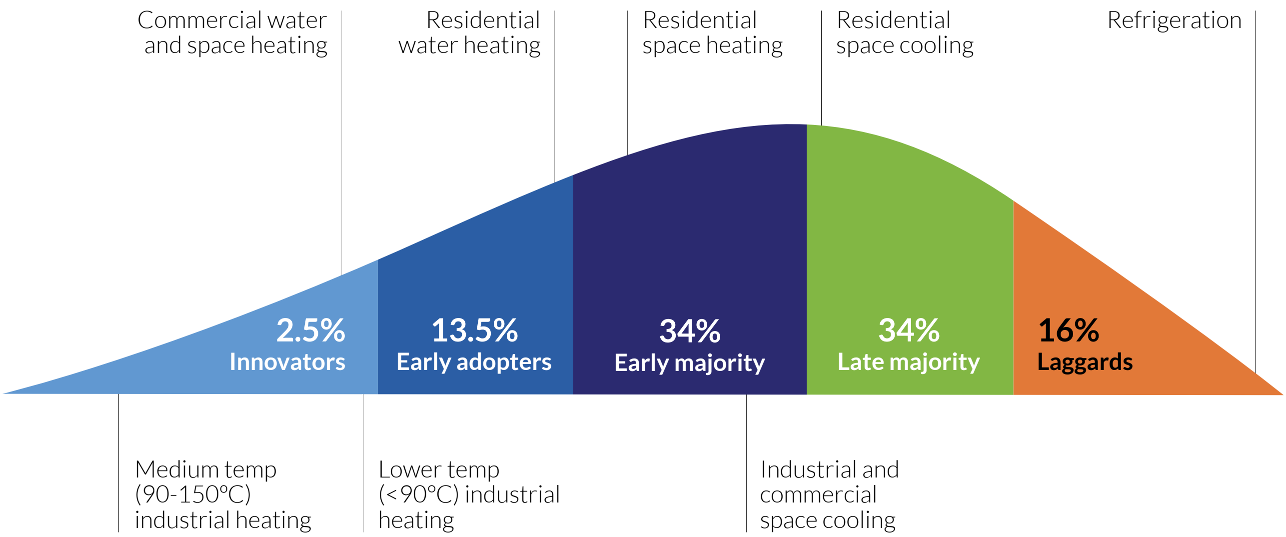


Figure 14 Estimated adoption level for heat pump technologies along Rogers diffusion curve

4.1 Barriers to uptake

Energy efficiency activities, including heat pump deployment, are often very low-cost sources of emissions reduction, providing a financial return in addition to energy savings and emissions reduction.[65] Energy efficiency and productivity measures have also long been recognised to deliver multiple benefits, contributing to improved economic, health and security outcomes.[66]

However, energy efficiency literature also recognises that there are a range of barriers that inhibit take up of energy efficiency measures, despite their benefits. Typical barriers include:

- Market failures;
- Behavioural, cultural and organisational barriers;
- Opportunity costs; and
- Policy uncertainty.[67]

These barriers can be exacerbated where markets and supply chains lack maturity.

Market failures can include information gaps and split incentives, which are significant barriers to optimal decision-making about investment in energy efficient equipment like heat pumps. Decisions to make an investment in heat pump technologies can also be influenced by opportunity costs of lost production while installation takes place, or an opportunity cost of alternative uses of capital. Different sectors – residential, commercial and industrial – face different barriers to uptake.

A survey of EEC and A2EP members and stakeholders – typically well-informed energy services professionals, government representatives and consumer advocates – identified the greatest barrier to heat pump adoption as 'end user awareness'. The second biggest barrier was 'installer awareness', with 'upfront costs' being a leading barrier for commercial buildings – see *Appendix 3* for further information.

Experience from Europe has also highlighted financial barriers as a key challenge to the adoption of heat pumps, as some types of heat pumps currently have higher upfront costs – made up of equipment, design and installation costs – than comparable gas or resistive electric appliances. Additional challenges can also include the availability of skilled installers and trades, acceptable integration of heat pumps into the built environment, and managing the impact of heat pumps on electricity networks.[68]

65 See, for example, Energetics 2016, *Modelling and analysis of Australia's abatement opportunities,* Energetics, Sydney, p. 20, 30 & 39; The Centre for International Economics (CIE) 2019, *What existing economic studies say about Australia's cost of abatement*, CIE, Canberra, p. 30-33.

66 International Energy Agency (IEA) 2015, *Capturing the multiple benefits of energy efficiency*, IEA, Paris, p. 20.

67 Climate Change Authority (CCA) 2020, *Prospering in a low-emissions world: an updated climate policy toolkit for Australia*, CCA, Canberra, p.131.

68 Association of the European Heating Industry (EHI) 2021, *Rolling out heat pumps: barriers and how to overcome them*, EHI, Brussels, p. 5-9.

4.2 Pathway to deployment

This report proposes a seven-step conceptual pathway for unlocking the savings in energy and emissions that heat pumps could deliver:

1. **Strategy**;
2. **Research and development (R&D)**;
3. **Experience and early deployment**, including pilot projects;
4. **Regulation and standards**;
5. **Integration** with renewable energy sources;
6. **Awareness**, including guides, training, and campaigns; and
7. **Deployment at scale**, including incentives.

Collectively, these steps address a range of barriers to adoption. Action is not needed against all seven areas for all applications in all sectors. However, action across the seven areas would be necessary to achieve whole-of-economy adoption, and each step on the path can be supported by appropriate policy measures.

4.2.1 Strategy

Strong, overarching frameworks for emissions reduction across the economy are important to send clear policy signals to households, businesses and government. Strategic policies should include sector specific pathways and a robust suite of actions from government to accelerate decarbonisation.

The *Trajectory for low energy buildings* provides a clear framework for action in the building sector that can help enable accelerated adoption of a range of technologies and practices, including heat pumps. An equivalent framework for Australia's industrial sector could play the same role, supporting the adoption of heat pumps as part of a broader suite of low emissions technologies and practices in the manufacturing sector and beyond.

For optimal effect, overarching strategic frameworks should be complemented by targeted actions that recognise the varying levels of maturity in specific heat pump markets. For example, RCAC in residential and small to medium commercial buildings are common in Australia. The RCAC market has sophisticated supply chains, a large installer base and established minimum energy performance standards (MEPS) and efficiency labelling. In this market, action could focus on policy and incentives to accelerate the rollout.

At the other end of the spectrum, the use of heat pumps for process heat in manufacturing and food processing is embryonic. Realising the opportunity requires action at all stages on the pathway to deployment, with a focus on supporting early deployment and research and development that addresses challenges encountered in particular subsectors.

BOX 3: Strategy in action in the United Kingdom

The United Kingdom has developed a set of policies that provide clear guidance and strategy on decarbonisation across the economy.

Overall policy is guided by the UK's 2020 *Energy White Paper* that sets out the UK Government's general policy settings for energy and emissions reduction to net zero, as well as guidance on policy direction in each sector.[69]

High-level strategy is supported by sectoral policy guidance. The UK's *Industrial decarbonisation strategy* identifies priority actions and key technologies, such as heat pumps, to reduce emissions and improve efficiency across all industry sectors.[70] The *Heat and buildings strategy*, released in October 2021, details how the UK Government aims to build the market for heat pumps so that 13 million heat pumps would be used in British homes by 2050.[71]

4.2.2 Research and development (R&D)

Research and development is an important part of the ongoing path to wide-scale deployment. Early-stage R&D develops new technologies for implementation, and ongoing research, development and demonstration helps create innovations that lower the cost of deployment, improve product performance, and broaden technology application.

For many applications, highly efficient heat pumps are available on the market today. However, even the most advanced countries in heat pump adoption – Japan, Sweden and the United States – maintain ongoing R&D efforts to continuously improve product performance.

69 UK Government 2020, *Energy white paper: powering our net zero future*, UK Government, London.

70 UK Department for Business, Energy and Industrial Strategy (BEIS) 2021, *Industrial decarbonisation strategy*, BEIS, London, p. 63.

71 UK Department for Business, Energy and Industrial Strategy (BEIS) 2021, *Heat and buildings strategy*, BEIS, London, p. 156.

A variety of policy levers can encourage R&D efforts, including targeted financial support, clear innovation policy, regular improvements in minimum standards, and facilitating collaboration between researchers, industry and government on national priorities. Government performs several functions in facilitating R&D:

- As an **investor**, providing resourcing for early-stage R&D;
- As a **coordinator**, identifying priorities for national effort across the innovation system; and
- As a **facilitator**, by creating systems that enable R&D, such as the higher education system and business innovation systems.

Australia has a range of programs that operate at various points along the innovation pipeline that could support R&D for deploying heat pump technology, directly or indirectly. These include ARENA, the CEFC and funding for R&D delivered through the Australian Research Council. Australian efforts can also learn from successful international programs to stimulate R&D, such as Japan's Top Runner program – see **Box 4**.

BOX 4: Continuous improvement – heat pump R&D in Japan

Japan has established itself as a leader in heat pump hot water systems through strategic R&D and innovation activities. Government and industry continue to work towards improving product performance and efficiency, through industry-led R&D and policy that encourages continuous improvement.

Japan's *Central Research Institute of Electric Power Industry* undertakes research into steam and high temperature heat pumps. The Institute has established a test facility for heat pumps to improve their performance with a view to expanding their use. This provides valuable data which can be used to enable deployment.

The Japanese Government's *Top Runner* program drives efficiency improvements in heat pumps and other types of equipment by setting multi-year targets for efficiency levels of equipment and rewarding the manufacturer of the most efficient product at the end of the target period. All products must reach the target efficiency level by the end of the period. The competitive nature of this program fosters innovation amongst manufacturers and incentivises continuous improvement.

The university system also houses significant R&D capacity that can be harnessed towards locally relevant R&D, including through the long-established Cooperative Research Centres program – see **Box 5**.

BOX 5: Collaborative R&D in Australia

Cooperative Research Centres (CRCs) are a long-standing Australian Government vehicle for driving collaborative R&D between industry and universities.

The *Reliable, Affordable, Clean Energy (RACE) for 2030 CRC* – which joins energy industry businesses with researchers – conducts research relevant to the role of heat pumps in supporting:

- Emission reductions;
- Optimised investments in solar PV with electrification;
- Reliability and stability improvements from flexibility and thermal storage;
- Improved health outcomes; and
- Energy bill reductions.

RACE for 2030 is investigating heat pump technology as part of its work on industrial decarbonisation, as well as exploring ways that smart, efficient homes can contribute to grid stability.

International collaboration on R&D

Australia is a relatively small economy and market by global standards, and remains a net importer of technology, knowledge and expertise. It remains in Australia's interests to be closely engaged with international R&D in heat pumps and other abatement technologies to facilitate rapid access to technological developments. International collaboration occurs at a range of scales, from collaborations between individual researchers, through to national participation in international efforts such as Mission Innovation 2.0, and the Technology Collaboration Program on Heat Pumping Technologies – see **Box 6**.

BOX 6: The IEA's role in fostering global technology collaboration

Many of the global leaders in heat pump development and deployment participate in the *International Energy Agency's Technology Collaboration Programme (TCP) on Heat Pumping Technologies (HPT)*.

IEA TCPs support the work of independent, international groups of experts by facilitating collaboration between governments, researchers and industries on a wide range of energy technologies and related issues. The experts in these collaborations work to advance the research, development and commercialisation of energy technologies.

The TCP on HPT focuses on accelerating the implementation of heat pumps through knowledge- and experience-sharing.

BOX 7: ARENA pilots

In Australia, the Australian Renewable Energy Agency (ARENA) is playing an important role in building experience by funding pilots of early deployment of heat pumps in partnership with industry and researchers.

ARENA is funding a *pilot of mechanical vapour recompression (MVR) heat pump technology* to reduce energy and emissions in alumina processing – see *Section 7.2.3* – and a study of deployment of *ground-source heat pumps* in a new housing estate in Sydney.

ARENA provides funding and impetus to advance experience and early deployment activities, as well as maximising the value of investments through a robust knowledge-sharing framework.

4.2.3 Experience and early deployment, including pilot projects

Following R&D phases, piloting is necessary to move technology into practical applications. Demonstration of heat pump products – through feasibility studies or pilot projects – can prove to the market that these products work well and perform at high levels of efficiency, while also building market experience for manufacturers, installers and distributors.

Pilots in particular can play an important role in demonstrating to consumers and industry that heat pumps achieve expected levels of energy and cost savings. Where deployment of heat pump technology requires more complex integration into existing processes – such as in manufacturing businesses – pilot projects can demonstrate that such processes can be successfully transitioned to utilise heat pumps. They also help develop critical skills and knowledge within businesses and among the professionals supporting businesses to move to heat pump technology.

Pilot programs should identify the specific market gaps and barriers to be addressed for a particular application while supporting market leaders. It is also important to ensure results from these studies are well utilised as part of information and awareness campaigns targeted at consumers – see *Section 4.2.6*.

4.2.4 Regulation and standards

Developing robust governance and assurance mechanisms is important to build consumer confidence and trust. Effective regulation, standards and compliance mechanisms act to overcome market failures such as information gaps through energy rating labelling and MEPS. Codes and standards like MEPS provide a guide against which product performance can be measured. This is particularly important for enabling consumer choice and building confidence in the industry.

Equipment

Energy rating labelling and MEPS, assured by a rigorous compliance regime, can support the growth of a domestic market for heat pumps in Australia and capture global economies of scale. These measures – already in place for RCACs – ensure that consumers can be confident that they will realise energy savings, and that product performance meets acceptable levels. In 2018 alone, Australia's Equipment Energy Efficiency program – comprising energy labelling and MEPS – saved consumers between $1.13-2.15 billion and avoided between 4.8 and 7.6 Mt CO_2e in emissions.[72] Energy performance ratings and MEPS are common in other jurisdictions, such as the EU's *Energy Label* and *Ecodesign* standards, and United States' *Energy Star* program.

72 Collyer, A. 2019, *Independent review of the Greenhouse and Energy Minimum Standards Act 2012*, Commonwealth of Australia, Canberra, p.16.

Energy labels and MEPS have different, but complementary aims. Labels provide consumers with information to assist them in making decisions, while MEPS remove the worst-performing products from the market. Labelling is most useful when directed towards consumers who may not be assisted by a professional when deciding which equipment to purchase, while MEPS can be more broadly applied where sufficient volume of product sales exist to justify imposition of regulation.

Where possible, harmonisation with international standards – for example, those in the EU – has a double benefit. It aligns Australian requirements with those of other major markets, raising minimum energy efficiency standards while maximising the range of products available to consumers. It may also open up opportunities for Australian manufacturers to export heat pumps or heat pump components overseas, in line with the Government's ambitions to foster local manufacturing and deployment of low-emissions technology.

Buildings

Building codes are an important tool for ensuring that new buildings contain suitable energy efficiency solutions for heating and cooling. Building codes overcome market failures such as split incentives between building developers and occupants. The NCC is progressively being updated to increase thermal performance and energy efficiency of new buildings. Over time, this is expected to support the adoption of heat pumps.

Other measures can support improvements of existing buildings, such as disclosure of energy performance to renters and purchasers. This can provide crucial information to the market, and increase demand for higher efficiency solutions. The National Australian Built Environment Rating System (NABERS) and the Commercial Building Disclosure (CBD) program have driven significant energy performance improvements in Australia's office sector over the last decade; equivalent measures in other commercial building types and in residential buildings would encourage the deployment of high efficiency technologies, including heat pumps.

BOX 8: Mandatory energy performance disclosure in the UK (and the European Union)

In the United Kingdom – and the EU – an *Energy Performance Certificate (EPC)* must be disclosed when a residential building is built or offered for sale or lease. The EPC presents a simple, visual rating of the energy performance of the building, along with an indication of the building's potential energy performance. The policy has been in place in the UK since 2008.

Mandatory disclosure of energy performance prior to sale helps to overcome several market failures, including information asymmetry and split incentives. *Studies into mandatory building disclosure schemes* have shown a positive relationship between more efficient homes and home prices, suggesting that buyers may place a value on home efficiency. This can help improve the case for investment in efficient residential technologies, like heat pumps.

Refrigerants

Refrigerant standards can minimise GWP and greenhouse gas emissions associated with heat pump products. Any policies or programs that support increasing the market penetration of heat pumps need to be designed to avoid creating or exacerbating downstream issues from poor refrigerant selection, and paired with complementary efforts to phase out high GWP refrigerants.

4.2.5 Integration with renewable energy sources

The modelling undertaken for this report – see *Section 3.3* – finds that the fuel-switching to electricity that would result from wide-scale deployment of heat pumps would marginally increase electricity consumption, but drastically reduce overall energy consumption.

Fuel-switching and upgrading equipment also provides the opportunity to integrate heat pump technology with renewable energy. Wide-scale deployment of heat pumps needs to be undertaken with a focus on how they interact with electricity grids with a high penetration of variable renewable energy.

A variety of opportunities for matching heat pump operation to renewable energy exists. Simple solutions include using timers to use RCACs and HPHWS at times of high renewable generation during the day. More sophisticated solutions for commercial and industrial applications can make heat pump technology responsive to market signals like the Wholesale Demand Response Mechanism (WDRM), spot market prices and peak demand charges.

Concurrently undertaking other energy efficiency measures alongside the installation of heat pumps can enhance the opportunity to support the grid. For example, in the residential sector installation of a new heat pump space heating solution could be paired with installation of insulation and gap sealing, maximising the potential for pre-heating and cooling, which could help to ameliorate minimum demand issues in the middle of the day and peak demand in the evening.

BOX 9: Smart grid integration

Around the world, energy markets are beginning to harness the benefits of integrating small-scale renewable energy generation, storage, control mechanisms and smart technology into virtual power plants (VPPs). VPPs aggregate hundreds of small generating stations and batteries into a large resource that can be centrally controlled, providing additional resources to the grid for demand response, stability and resilience.

Advanced processing and aggregation platforms can provide opportunities to individual householders to participate in the energy market, which can lead to financial benefits for all parties.

In the United States, policymakers have *cleared the way* for VPPs and other distributed resources to compete with existing generators in federally regulated markets. VPPs participate in the UK's Balancing Mechanism. In Europe, *the largest VPP* contributes more than 10 GW of installed capacity to the electricity market.

The principles behind VPPs can equally be applied to flexible loads like heat pumps, creating opportunities for demand-side participation in energy markets.

4.2.6 Awareness, including guides, training and campaigns

Building awareness is critical to diffusion of new technologies. Conventional gas and electric resistance technologies have the highest market share for most of the applications in this report. Many consumers – and the professionals and suppliers that operate in these markets – are familiar with conventional technologies and unaware of the benefits of heat pumps. Even if they have some level of awareness of heat pumps, they may not know how to gain the most benefit from this technology, or about important issues such as the need to regularly clean filters.

Training and professional development

Interviews and surveys undertaken for this project made it clear that one of the biggest barriers to the large-scale adoption of heat pumps is lack of awareness of heat pump technology in both end users and installers.

Building awareness, skills and expertise amongst relevant trades and professions such as electricians, plumbers, builders, engineers, building designers, architects and certifiers, and facilities managers would help create a critical mass of professionals who understand the benefits of, and barriers to, heat pumps. Suitably experienced professionals can guide households and businesses to make informed decisions, and are key to moving heat pumps along the diffusion curve.

Results of early deployment and experience initiatives, such as pilot studies, should be communicated to trades and professions effectively, giving them the information they need to confidently recommend heat pumps to consumers.

Consumer resources

Simple resources, clearly targeted for consumers with low technical literacy, play a role in supporting consumer awareness and facilitating consumer choice. The Building Energy Exchange – an initiative of the *New York State Energy Research and Development Authority* – has made a range of information resources around heat pumps available to consumers.

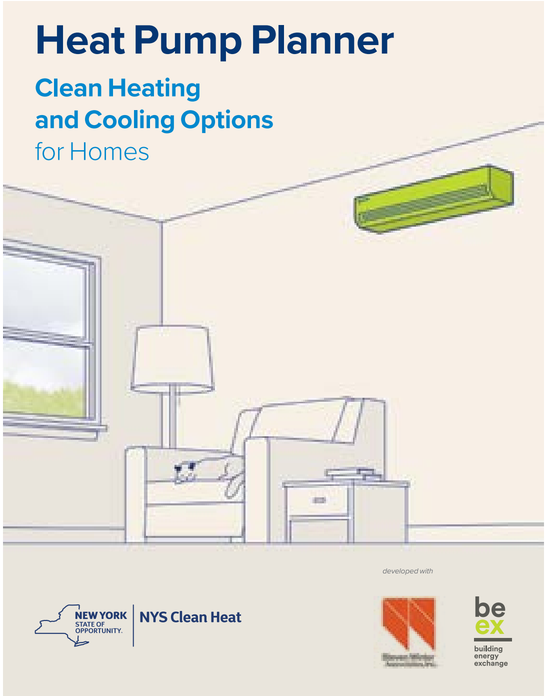


Figure 15 The New York State Energy Research and Development Authority (NYSERDA) supports households with switching to heat pumps with simple resources

Source: Building Energy Exchange 2021, *Heat pump planner*, New York State Energy Research and Development Authority, Albany.

One such resource is the *Heat pump planner*, which helps consumers determine the best heat pump system for their home – see **Figure 15**. In Australia, AIRAH has recently relaunched its FairAir calculator that allows consumers to estimate energy use and sizing of residential heat pumps, and the Australian Energy Foundation has released heat pump guides for *hot water systems* and air-conditioning.

Businesses can also benefit from resources to help make informed decisions about investing in heating and cooling equipment. The information needs of many small businesses are similar to those of households; they need accessible, straightforward materials that don't assume a high degree of technical literacy. However, larger businesses – and energy intensive small businesses – are likely to require tailored advice from a skilled professional to select and design a system to suit their needs.

BOX 10: WPesti wins big

Switzerland has created a performance assessment tool – WPesti[73] – that considers multiple applications where heat pumps may be used, including residential. This tool is widely used and well regarded, and has been validated over the last decade by measurement and verification (M&V).

The calculation and determination of the relevant quantities, including heating loads and seasonal savings, is based on Swiss standards for thermal performance assessment. It covers air-source and ground-source HPHWS models offered in Switzerland, as well as a selection of heating applications.

This tool considers 32 Swiss climate zones and follows an assessment procedure – the climate bin approach – that is similar to, but broader in coverage than the procedure for RCAC energy efficiency rating as per Australian Standards used for MEPS, which consider only three climate zones for Australia.

Industry associations and groups

Some nation states and regional groups – like the EU – have associations with the specific goal to develop the local heat pump market. The *European Heat Pump Association* represents the heat pump industry and promotes awareness and deployment of heat pumps in the European market. The *Swedish Refrigeration and Heat Pump Association* provides a forum for heat pump manufacturers to bolster consumer trust in the technology.

Development of a heat pump council has also been encouraged in the United Kingdom, where large-scale deployment of heat pumps has become a significant part of the UK Government's strategy to reduce emissions in buildings. The proposed heat pump council would support consumer awareness and consumer protection, as well as promote technical standards and supply chain development.[74]

4.2.7 Deployment at scale, including incentives

Even if consumers are aware of the benefits of heat pumps and would like to adopt the technology, upfront cost can still be a barrier. Provision of incentives and other financial measures can be an important ingredient in the market transformation for whole-of-economy heat pump adoption.

Financial incentives can move technology along the diffusion curve, raising consumer awareness, helping supply chains mature, and supporting installers and other professionals to gain experience with the technology.

Incentive programs should be paired with other measures – such as professional training and consumer awareness programs – and designed to track market capacity. As market capacity increases, incentive programs can be scaled up, ensuring a high level of service and performance quality. As upfront costs come down, supply chains mature and a sophisticated design and installer base is established, incentive programs should be scaled back.

BOX 11: Tax credits and subsidies to enable deployment at scale

In Sweden, tax credits for the replacement of oil heaters with heat pumps, as well as tax reductions for labour associated with heat pump installations, have been used as part of a broad toolbox of measures to successfully drive heat pump adoption.[75]

In Germany, the Federal Government's 2019 Climate Package subsidises heat pump installations when replacing an existing gas or oil heater.[76]

The Australian Government's new and expanded tax incentives could be effectively leveraged to support the uptake of heat pumps in commercial and industrial settings.[77]

73 Intercantonal Energy Directors' Conference (EnDK), n.d., *Hilfsmittel*, EnDK, Bern, Switzerland.

74 Lowes, R., Rosenow, J. and Guertler, P. 2021, *Getting on track to net zero: A policy package for a heat pump mass market in the UK*, Regulatory Assistance Project, Brussels, p. 21.

75 Lopes, C. 2019, *Factors for enhancing the market development of energy efficient eat pumps – scaling up through European policy instruments*, European Council for an Energy Efficient Economy (ECEEE) Summer Study Proceedings, Stockholm, p. 1677- 1685.

76 Federal Ministry for Economic Affairs and Climate Action (BMWK) 2021, *New 'Federal Funding for Efficient Buildings'*, BMWK, Berlin.

77 Energy Efficiency Council (EEC) 2021, *Leveraging tax incentives to improve energy performance: a guide for Australian businesses investing in smart energy management*, EEC, Melbourne.

4.3 Choosing the path – comparing opportunities

This report explores a range of opportunities to deploy heat pump technology in residential buildings, commercial buildings and in industrial processes. In many instances, governments are well-placed to help accelerate deployment to rapidly achieve savings in energy and emissions reductions through well-designed policy and programs.

However, competing priorities frequently mean that decisions must be made about the most effective use of limited resources, which necessitates prioritisation of opportunities to accelerate heat pump deployment.

4.3.1 Factors influencing ability to achieve energy and emissions abatement

This exercise in prioritisation is a matter for individual governments. However, several factors should inform decision-making.

Scale of opportunity

The *Heat Pump Energy and Emissions Savings Model* developed for this report clearly identifies that the largest opportunities for reducing emissions through heat pump technology is in industrial processes, followed by residential buildings. In industrial processes, changes to a single industrial site or process may yield substantial reductions in energy usage and emissions, while the large opportunity in residential buildings could be achieved through heat pump upgrades to millions of individual premises.

Timeframe to realise savings

Energy and emissions savings from heat pump technology can only be realised once heat pumps are available for deployment. This requires that for each application, the technology is mature, and has a medium to high level of commercial maturity. For residential applications, heat pumps are technologically mature, and have an adequate level of commercial maturity in Australia for all applications. This suggests that abatement can be realised from the residential application of heat pumps immediately, with efforts centred around accelerating deployment to take early advantage of the potential savings.

At the other end of the scale, heat pumps for industrial processes have a variety of levels of technological and commercial readiness. For some processes such as process water heating, piloting could help catalyse deployment of technology within the next three to five years. In other applications – such as delivery of higher-temperature heat – more extensive R&D and piloting is required to bring the technology to acceptable levels of technological and commercial maturity. This means that opportunities to reduce industrial emissions from heat pumps are likely to be a longer-term proposition, although immediate action is required to ensure the technology achieves readiness in time to support Australia's transition to net zero emissions.

Agency

Recognising that deployment of heat pump technologies faces barriers and market failures, government action can be critical to unlock abatement through the adoption of heat pump technology. However, action on this front lies within the competence of a range of actors, including Commonwealth, state and territory governments, as well as industry, consumers and business. For example, the Australian Government is well placed to invest in R&D activities on behalf of the wider community, whereas state governments have access to a range of policy levers that could support the decisions of individual householders to install heat pump technology in their homes.

Some activities may be best undertaken in partnerships between different actors – for example, upgrades to building codes are undertaken by Commonwealth, state and territory governments acting together. Upgrades to training and professional development can be undertaken by governments in partnership with industry and professional associations.

Spillover benefits

Government interventions have the potential to create spillover benefits. Policy design could also examine the indirect impacts of government action to maximise the value of investment. For example, well-designed government programs can quickly bring scale and build market confidence. For example, a government making a large investment in heat pump technology across its portfolio of social housing could catalyse increased product availability, and enhance skills and experience of trades and professions.

It is also worth considering the benefits of interventions beyond the sector being addressed, as actions that accelerate heat pump deployment in one sector are likely to have flow-on effects for deployment in other sectors.

For example, building skills in heat pump installation in residential settings creates a pool of skilled trades who could quickly adapt to working with larger heat pumps installed in commercial buildings. In turn, increased deployment of heat pumps to replace gas boilers in commercial buildings could achieve economies of scale, enabling better availability and experience with products that could be used in industrial processes.

Considering the broader benefits of particular actions may help governments weighing up the relative benefits of interventions.

4.3.2 Weighing relative merits of interventions

Accelerating the deployment of heat pumps is an opportunity to reduce emissions in Australia. However, given limits to resources, as well as the opportunity costs of action, any intervention to accelerate heat pump deployment should consider which actions would make the most effective use of government resources. This requires balancing considerations of cost and resources against scale, timeframe, agency and potential for spillover benefits.

For example, immediate action to encourage heat pump deployment in residential buildings with readily available RCACs and HPHWSs could bring rapid and significant cuts to greenhouse gas emissions. A variety of existing policy levers are available to Commonwealth, state and territory governments to encourage rapid deployment of heat pump technology in residential buildings.

Abatement from heat pumps in industrial processes is a large opportunity but will require significant effort to realise the potential emissions and energy savings. Efforts to ensure that these technologies can reduce emissions in the medium term – through targeted R&D, piloting and knowledge-sharing – is an important near-term priority.

While the scale of energy and emissions savings in commercial buildings is lower, mature policies and commercial ecosystems to support upgrades to commercial buildings means that the effort needed to drive change is modest relative to other sectors. Continued, steady action to encourage increased efficiency through heat pump deployment will yield significant cumulative abatement over time. Smaller initial actions, such as demonstration projects of commercial building retrofits, will play an important role in enabling progress in reducing energy usage and emissions in the commercial buildings sector, and are within the ability of existing government mechanisms such as ARENA and the CEFC to leverage.

4.4 Cross-cutting issues for policy development

Deployment of heat pumps presents opportunities for emissions reduction and energy savings, however there are economy-wide issues that should be considered when designing any policy measure to accelerate deployment of heat pumps. These are:

- Skills and workforce development;
- Innovation and R&D;
- Effective regulation and standards; and
- Integration with renewable energy.

4.4.1 Skills and workforce development

Across all sectors, lack of experience with heat pumps among the trades and professions that design, sell, install and maintain heating systems is a barrier to adoption. Building designers, engineers and certifiers, facilities managers, plumbers, electricians, and refrigeration mechanics are key occupations for heat pump design, installation and maintenance.

Building a heat pump workforce with high levels of skills and experience is an important element of any program to accelerate heat pump deployment. A skilled workforce is likely to deliver improved quality and safety outcomes, and provide a level of assurance and risk mitigation for government in any program.

Training and skills development could take different forms, relative to the challenge. A pressing need is to ensure that tradespeople have the required mandatory occupational licencing to install heat pumps, which would be delivered through existing channels such as registered training organisations (RTOs). Further optional training and/or certification – similar to the European Union's *EUCert* – could also support improved quality, and could be delivered through industry associations or other industry participants.

While ongoing skill shortages across a large number of trades and professions present a broader challenge for the economy, measures such as joint delivery or co-investment between government, industry and professional bodies to encourage manufacturers and professionals to deliver up-skilling and professional development would help remove a key barrier to heat pump deployment.

4.4.2 Effective standards and regulation

Effective product standards and regulation can overcome market failures like information asymmetry. This is particularly important for consumers, who are less likely to have access to the necessary expertise and resources to determine whether a particular product or service is suitable for their requirements.

Effective regulation helps build confidence by ensuring that consumers have the necessary information to make suitable purchases and can access remedy through consumer protection legislation, which lowers the likelihood of an adverse outcome for consumers. The Equipment Energy Efficiency (E3) program is a good example of an effective regulatory scheme. It has delivered significant cost savings to consumers, as well as energy and emissions savings that benefit the wider community.[78]

However, while regulation is an effective tool to overcome some barriers to deploying heat pumps, excessive regulation can have negative effects for consumers through increased cost and potentially reduced choice if regulatory burden dissuades manufacturers from offering products to the market.

Regulation and standards are important levers available to government to achieve policy outcomes. Identified areas for development in regulation in standards include:

- Extension of E3 measures beyond RCACs to other heat pump types, particularly labelling and MEPS for domestic HPHWS; consideration could also be given to labelling and MEPS for heat pumps for small commercial applications, and MEPS for packaged heat pumps;
- Building codes and regulation influence choice of installed heating and cooling services; increased energy efficiency ambition in building codes will encourage installation of appliances like heat pumps with lower energy usage and emissions;
- Expanding building energy performance disclosure to other commercial building types, as well as residential dwellings; and
- Introducing minimum standards for rental dwellings that ensure renters have access to affordable, clean and efficient heating and cooling.

78 Collyer, A. 2019, *Independent review of the GEMS Act 2012 - final report*, Australian Government, Canberra, p.4.

4.4.3 Integration with renewable energy and the electricity grid

Deployment of heat pumps to replace gas infrastructure could unlock substantial emissions savings, particularly where they are integrated with renewable energy. At the same time, electrification will have impacts on the electricity grid as new electric heat pumps come online. Managing the impacts on the grid is an important consideration for policy and will be most effectively managed through advanced planning and policy settings. Understanding and modelling grid impacts in advance will allow for optimal investment decisions, both by consumers – particularly large industrial consumers – and electricity market stakeholders.

Electrification of heating loads opens the potential for demand flexibility and management, particularly where thermal storage – like hot water tanks or building thermal mass – is used. Thermal storage, coupled to heat pumps and renewable electricity, is an opportunity to provide heating and cooling at very low operating cost and emissions. In some instances, this provides the opportunity to run heat pumps to produce heat when renewable energy production is high and to store the energy for times of peak demand. Where applications allow flexible running of heat pumps, demand can be shifted away from peak periods. This can be achieved through pre-heating and cooling in buildings, or running heat pumps to store hot water at off-peak times.

In some cases, demand flexibility can be achieved through simple measures, such as programming a hot water system to run during times of peak solar PV generation. In other applications, more sophisticated demand response integration may be required. Unlocking this potential requires enabling infrastructure – such as market signals and aggregation platforms. Building and refining this infrastructure would require a coordinated national effort, and efforts to encourage heat pump adoption would deliver greatest benefits when the potential for flexible operation is considered.

Actions to support this outcome could include efforts at all stages of the innovation chain – such as demonstration and pilot studies through innovation frameworks, policy development on reducing barriers to participation in energy market mechanisms, and incentives for deployment of demand response enabled devices (DRED) through state and territory energy efficiency schemes.

4.4.4 R&D, innovation and knowledge-sharing

Ongoing R&D is likely to yield continual improvements in the performance and potential application of heat pumps. Continual innovation will expand the utility, affordability and application of heat pumps. Australia will benefit both through encouraging targeted onshore R&D and innovation, and through close engagement with international heat pump innovation. Developing partnerships between researchers, businesses and relevant government stakeholders both domestically and internationally, will promote improved knowledge-sharing and technology diffusion.

Highly efficient heat pumps are available on the market today. However, as mentioned in *Section 4.2.2*, even the most advanced countries in heat pump adoption are investing heavily in R&D to enhance and expand the application of heat pumps. Close engagement with international technology development efforts such as the International Energy Agency's Technology Collaboration Programme (TCP) on *Heat Pumping Technologies* can leverage global R&D efforts to address particular challenges of heat pump adoption in Australia.

Knowledge-sharing has been highlighted as a key avenue for improving heat pump deployment, as lack of familiarity and expertise amongst professionals has been identified as a barrier to heat pump adoption in Australia. Dissemination of experiences from pilot and demonstration projects will allow greater confidence in heat pump deployment – particularly in commercial and industrial applications. Although ARENA is well-suited to helping to disseminate knowledge and expertise from these types of projects, additional knowledge-sharing and awareness-raising will help maximise the benefits of any policy or program to accelerate heat pump deployment.

5

The opportunity in residential buildings

Summary

- Heat pump deployment in residential buildings could **save from 984 to 4377 PJ and 58 to 291 Mt CO_2e** by 2050.
- Residential heat pump hot water systems and reverse cycle air conditioners **are commercially available**, providing immediate opportunities for energy and emissions savings.
- Efficient and effective product standards and regulation can **support consumer confidence** in heat pump technology.
- **Awareness-raising amongst industry** and targeted incentives could help accelerate deployment at scale for heat pumps in residential settings.

5.1 Sector overview

Electrification of home appliances and services – paired with electricity sourced from renewable energy, and a thermally-efficient building shell – represents a cost-effective pathway to homes with net zero operational emissions. And the opportunity in this sector is significant.

Heat pumps in the residential sector are technologically mature and can deliver a range of thermal services, including space heating, space cooling, refrigeration, domestic hot water, and pool and spa heating – see **Figure 16**. In this section, substitution of heat pumps for domestic space heating and water heating has been modelled.

An ambitious goal to achieve 100% penetration of heat pump technology for residential thermal services could unlock substantial abatement. Switching from resistive electric heaters to heat pumps could significantly reduce energy and emissions associated with residential heating, especially in the near term. And coupling the very high energy efficiency of heat pump technology with fuel-switching from gas to electricity sourced from renewables would unlock significant additional abatement.

Table 7 shows that cumulative energy savings of up to **4,377 PJ** could be realised by 2050 with supercharged deployment – an amount of energy approximately equivalent to the remaining gas reserves in Victoria and South Australia.[79]

Heat pump penetration scenario	Cumulative energy savings to 2050 (PJ)	Cumulative greenhouse gas emission savings to 2050 compared to baseline (MtCO_2e) (ISP 2020)	
		AEMO 'Central'	AEMO 'Step change'
Late adoption 2040-2050	984	63	58
Linear to net zero 2050	2690	176	158
Linear to net zero 2050 + extra efficiency	4128	266	219
Supercharged deployment in 10 years (10% p.a.)	4377	291	260

Table 7 Residential buildings sector results from the *Heat Pump Energy and Emissions Savings Model*

79 Geoscience Australia 2021, *Australia's commodity energy resources 2021: Gas*, Australian Government, Canberra.

In residential applications, the largest energy and emissions saving opportunities exist in deployment of heat pump hot water systems (HPHWS), and reverse cycle air-conditioners (RCAC) that can provide both space cooling and heating services. Both appliances are commercially available and can be deployed in both new and existing buildings.

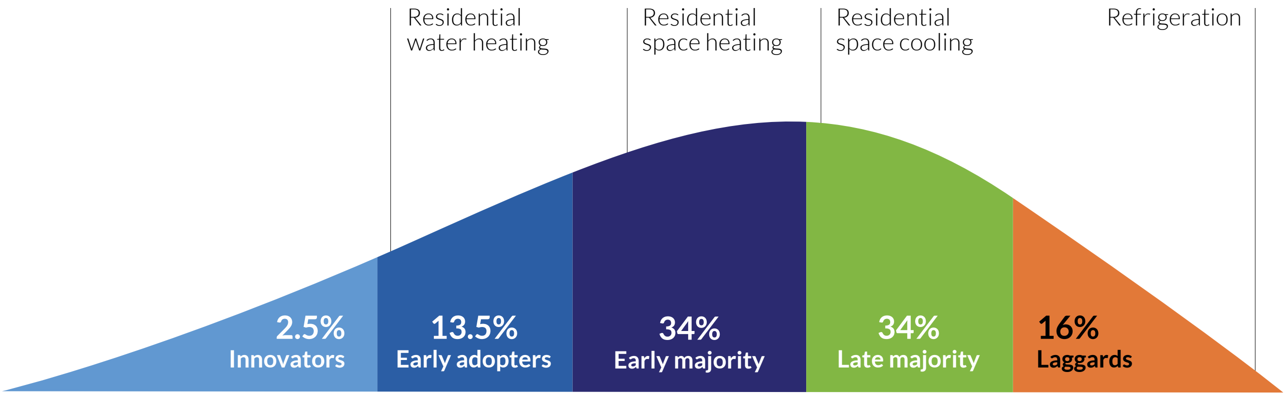


Figure 16 Estimated adoption level for heat pump technologies in residential buildings

More than 2.68 million Australian households – or one in four – have installed rooftop solar PV.[80] In these households, heat pump technology can be configured to utilise the PV system's output to provide hot water and space heating and cooling with near-zero emissions and running costs.

Targeted, well-designed policy measures could reduce barriers to mass deployment. Initiatives should seek to reduce both supply-side barriers – such as improving the skill base of installers – as well as stimulating demand by addressing information barriers that hamper adoption by end-users.

A priority recommendation to accelerate the development of heat pumps in residential technology is shown in **Table 8**.

	Activity	Actor
R1	**Develop and implement a heat pump deployment accelerator program for residential buildings, including:** **1. Introduction of E3 labelling and MEPS for HPHWS systems;** **2. Delivery of training and certification for tradespeople in residential heat pump installation;** **3. Awareness and education campaign for households on choosing and maximising benefits from heat pumps;** **4. Establish or expand programs to install heat pumps in low-income and vulnerable households; and** **5. Expand and enhance financial incentives for residential heat pump deployment.** Horizon: 1-5 years Areas: Strategy; Regulation and standards; Awareness; Deployment at scale	Commonwealth States and territories

Table 8 Priority recommendation for driving the adoption of heat pumps in residential buildings

80 Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2021, *Australia installs record-breaking number of rooftop solar panels*, CSIRO, Canberra.

BOX 12: Sweden's heat pump success story

Sweden's success deploying ground source heat pumps (GSHPs) can be traced to a range of factors.[81] Sweden's low electricity prices and limited access to natural gas meant the operating costs of heat pumps were not higher than alternative technologies. Adoption of heat pumps was accelerated through tax credits for the replacement of oil heaters with heat pumps, as well as tax reductions for labour associated with heat pump installations.

In the 1980s, the Swedish Government adopted a technology procurement policy that guaranteed initial demand for heat pumps that met required specifications, giving manufacturers confidence to invest in manufacturing capacity.

Bore hole drilling for GSHP has become efficient and cheap due to high demand, bringing down overall system costs. Research and development into heat pumps has been continuous since the 1970s, driving steady increases in efficiency.

The industry also benefits from a sophisticated ecosystem of installers. Manufacturers train installers, who are certified as a requirement under the EU Renewable Energy Directive. Installers are trained to correctly size, install and set up heat pump equipment.

Finally, a heat pump board has been established, giving consumers a dedicated channel for providing feedback to manufacturers, increasing product reliability.

The confluence of these factors has caused more heat pumps to be installed in Sweden than any other type of heater – see **Figure 17**.

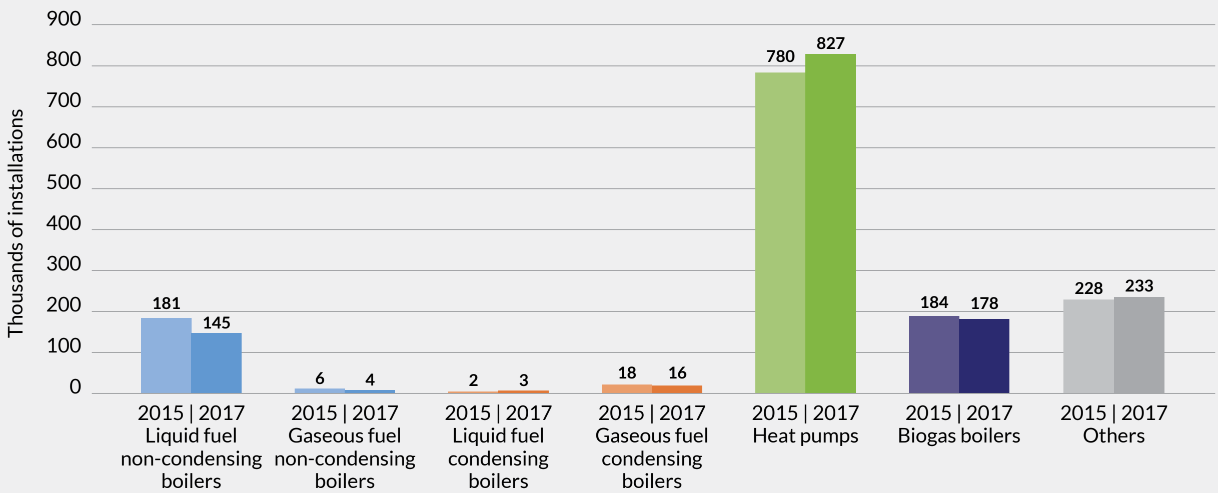


Figure 17 Installed stock of heaters in Sweden in 2015 and 2017

Source: Association of the European Heating Industry (EHI) 2020.

81 Association of the European Heating Industry (EHI) 2020.

5.2 Heat pump applications and opportunities in residential buildings

Of the three sectors examined in this report, heat pump deployment in residential buildings represents the most immediately accessible savings, with relatively low barriers to entry compared with commercial and industrial settings. Heat pump technology for space and water heating in the residential sector is mature, and while supply chains and skilled professionals are underdeveloped for HPHWS, this is an issue that can be readily addressed through focused effort from industry and government.

There are over ten million homes in Australia[82] which are responsible for 10.5% of Australia's total final energy consumption,[83] a quarter of Australian electricity consumption[84] and about 11% of Australia's national emissions.[85]

Over half (53%) of the energy used in residential buildings is electricity, with natural gas making up 42%. LPG and wood are used to a much smaller degree, at 3% and 6%, respectively.[86]

According to the *Model*, space heating (56%) and water heating (44%) would contribute similar amounts to the total potential abatement that could be realised – see **Figure 18** and **Figure 19**. As with all sectors examined, early adoption provides the greatest potential emissions savings.

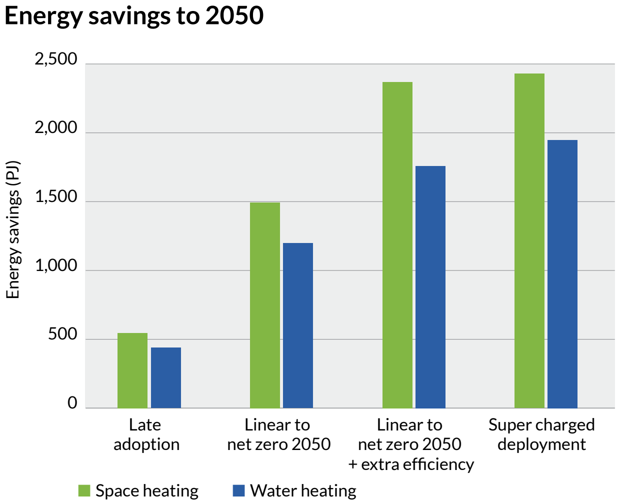


Figure 18 Potential energy savings from residential deployment of heat pump technology

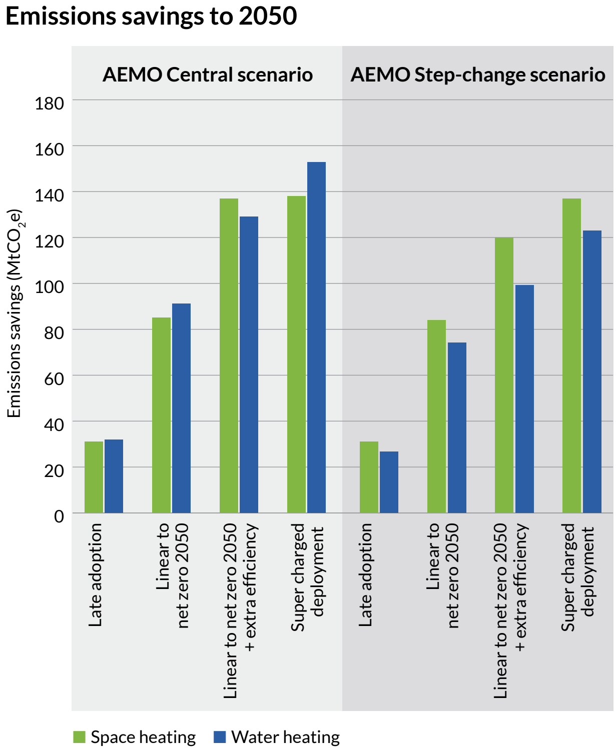


Figure 19 Potential greenhouse gas emissions savings from residential deployment of heat pump technology

82 Australian Bureau of Statistics 2022a, *Quickstats 2021 – Australia*, Australian Government, Canberra.

83 Department of Industry, Science, Energy and Resources (DISER) 2020, *Australian Energy Update September 2020* – Australian Energy Statistics, Commonwealth of Australia, Canberra, p. 17.

84 Department of the Environment and Energy 2018, *Australian Energy Update 2020 – Table A*, Commonwealth of Australia, Canberra.

85 Council of Australian Governments (COAG) Energy Council 2018, *Report for achieving low energy homes*, Commonwealth of Australia, Canberra, p. 8.

86 Energy Consult 2015, *Residential baseline study: Australia*, Department of Industry and Science on behalf of the trans-Tasman Equipment Energy Efficiency (E3) Program, Canberra, p. 18.

5.2.1 Australian opportunities

In Australia, assuming proper design and selection, heat pump technology can be deployed in both new and existing buildings, and in a wide variety of climate zones. **Table 9** characterises the variation in demand for various thermal energy services in the residential sector, all of which can be provided by heat pumps. **Table 10** estimates the current market penetration of heat pump technology in residential buildings.

Climate zone	Domestic hot water	Space heating	Space cooling	Pool heating	Refrigeration (cooling)
Climate zone 1: Hot humid summer, warm winter	High	Low	High	Low	High
Climate zone 2: Warm humid summer, mild winter	High	Low	High	Low	High
Climate zone 3: Hot dry summer, warm winter	High	Low	High	Low	High
Climate zone 4: Hot dry summer, cool winter	High	Medium	High	Medium	High
Climate zone 5: Warm temperate	High	Medium	High	Medium	High
Climate zone 6: Mild temperate	High	Medium	High	Medium	High
Climate zone 7: Cool temperate	High	High	Medium	High	High
Climate zone 8: Alpine	High	High	Medium	High	High

Table 9 Typical energy demand for common thermal energy services across climate zones – individual residential buildings

Building types	Domestic hot water	Space heating	Space cooling	Pool heating	Refrigeration
Standalone homes	Low	Medium	High	Low	High
Small apartment buildings	Low	Medium	High	N/A	High
Large apartment buildings	Low	Medium	High	Low	High

Table 10 Estimated heat pump market penetration in the delivery of common thermal energy services – residential buildings

BOX 13: Progress towards net zero-ready homes

Net zero-ready homes are a reality today. Well-designed, all-electric homes that couple efficient electric appliances with renewable energy, avoid greenhouse gas emissions, provide occupants with a comfortable, healthy environment at low ongoing costs, and negate the need for future retrofits. Building net zero-ready homes will be an important part of Australia's transition to net zero emissions, and there are signs that this trend is gaining traction. Volume home builders are beginning to aspire to greater levels of efficiency with low- to zero-emissions homes. SJD Homes, Metricon Homes and Stockland have all taken part in Sustainability Victoria's Zero Net Carbon Homes program to showcase energy efficient new homes while developing technical expertise amongst builders. These homes use efficient fixed appliances, with HPHWS offered as an option and reverse cycle air conditioners encouraged as part of the home design, and any energy used onsite is offset by 3.5kW to 6kW of solar PV. [87]

Water heating

Most water heaters in Australia currently rely on electric resistive elements or gas.[88] HPHWS consume on average one-third the amount of electricity of electric storage water heaters, with efficient models consuming even less. Compared to a resistive electric HWS, an air-source HPHWS would typically consume 65-75% less electricity and give rise to 65-75% less greenhouse gas emissions.[89] Comparisons to natural gas appliances are more difficult as they vary depending on the emissions intensity of the local electricity supply. However, a HPHWS coupled to on-site solar PV has the potential to reduce emissions from water heating by close to 100%, compared to natural gas appliances.

Households with existing resistive electric hot water systems may be able to utilise a HPHWS as a drop-in replacement, particularly if the location of the system is well-ventilated. By contrast, additional electrical work is generally required to replace a gas system with a HPHWS.

Residential-scale HPHWS have a high degree of technological and commercial readiness for standalone units, with many available off-the-shelf from recognised manufacturers. Larger, centralised hot water systems are less common in Australia, and have a slightly lower estimated commercial readiness.

Installation of small-scale air-source HPHWS attracts Small Technology Certificates (STCs) under the Small-scale Renewable Energy Scheme, offsetting the upfront cost of a HPHWS. Recent years have shown appreciable growth in HPHWS installations. In 2020, the Clean Energy Regulator reported 32,575 HPHWS installations based on claims for STCs, an increase from about 20,000 HPHWS sold in 2012.[90] In 2021, installations reached 52,739 units.[91]

87 Sustainability Victoria 2021, *Zero Net Carbon Homes*, Victorian Government, Melbourne.

88 Energy Rating 2020, *Water heating*, Australian, State and Territory and New Zealand Governments, Canberra and Wellington.

89 Sustainability Victoria 2021, *Compare water heating running costs*, Victorian Government, Melbourne.

90 Equipment Energy Efficiency (E3) 2012, *Product profile: Heat pump water heaters*, Australian Government Department of Industry, Science, Energy and Resources (DISER) and the New South Wales Department of Planning, Industry and Environment, Canberra and Sydney, p. 5.

91 Clean Energy Regulator 2021, *Postcode data for small-scale installations*, Australian Government, Canberra.

BOX 14: Heating pools with heat pumps

Australia has over one million swimming pools, many of which are heated using a conventional pool heater running on either gas or electricity in addition to a solar heater. Outdoor pools lose thermal energy to evaporation.

Most indoor residential pools are found in apartment buildings. Like aquatic centres, heating these pools can be very energy intensive, and there is substantial potential for energy recovery.

Pool pumps for filtration are covered by minimum energy performance standards and energy rating labels are required, however these requirements do not apply to pool heaters.[92]

Heat pumps for pools and spas are commercially available. Heating with a pool heat pump presents a big opportunity for reducing energy consumption, where it replaces an electric resistive or gas heater. Pool heat pumps can be paired with energy management to match heating with solar availability.

Most outdoor pools are not used in cold conditions, however careful equipment selection and design is required if the pool will be heated. Operation of heat pumps in cold conditions can lead to 'icing up' of heat exchangers, which impacts on both efficiency and capacity.

As pools are a clearly defined market and supply chain, pool heat pumps are likely to be cost-effective and accessed via a fairly simple policy or program. Managing pool pump energy use and demand management is being targeted through energy market mechanisms and specialist service providers.

Space heating

Heat pumps have achieved a high level of market penetration in the Australian residential sector for space cooling and refrigeration. Heat pumps are also somewhat common for space heating in climate zones that require heating; in 2014, reverse cycle air conditioners accounted for about 7.3 million existing heating units and 48% of new heater sales, with sales growing.[93]

Heat pumps utilised for space heating in residential buildings include split-system RCACs, multi-split RCAC systems that use a single external unit to power multiple indoor units, or ducted RCAC systems that can replace ducted gas central heating.

On the whole, the existing stock of residential buildings is of relatively low thermal performance – the average energy performance rating (NatHERS) for buildings built prior to 2005 in Victoria was only 1.8 stars[94] – meaning that replacing emissions-intensive heating systems will deliver substantial abatement.

Both air-source and ground-source heat pumps can be utilised for space heating. Ground source heat pumps have a major advantage in colder climates, as accessing a thermal energy source underground in these climates minimises the temperature difference between source and sink. The stability of this thermal energy has the co-benefit of improving system efficiency relative to ASHP.

However, GSHPs require drilling or excavation as part of the installation process, and Australia's relatively mild climate means that the benefits of GSHPs are unlikely to overcome the increased complexity of installation.

Hydronic systems that circulate heated water for space heating are also available. At least 700-800 hydronic heat pump units are sold in Australia annually,[95] with the market growing particularly for new homes and the retrofit of gas boilers. However, these systems often have higher upfront costs than other space heating solutions, meaning their take up is likely to be more limited.

92 Energy Rating 2020, *Swimming pool pumps*, Australian, State and Territory and New Zealand Governments, Canberra and Wellington.

93 Equipment Energy Efficiency (E3) 2021, *Residential space heaters in Australia & New Zealand*, Australian, State and Territory and New Zealand Governments, Canberra and Wellington, p. 30-34.

94 Sustainability Victoria 2019, *Comprehensive energy efficiency retrofits to existing Victorian houses*, Victorian Government, Melbourne, p. 74.

95 Indicative numbers provided by Stiebel Eltron market intelligence.

5.2.2 Global trends

Globally, fossil fuel-based and conventional electric technologies made up three-quarters of sales for space heaters and water heaters around the world in 2019.[96] By contrast, heat pumps made up a small – albeit growing – share of space and water heating appliances, up from 3% in 2010 to around 5% in 2019.[97] According to the IEA, meeting the goals of the Paris Agreement will require growth in heat pump sales to accelerate to around 22% of heating appliances sold globally by 2030.[98]

While average adoption rates globally are low, some countries have achieved very high penetration of heat pumps for space heating and water heating.

Heat pumps have reached the highest level of penetration in residential buildings in Sweden, where GSHPs dominate heating system sales at 93% of new heater sales.[99] GSHPs perform well in Sweden's very cold winters because ground temperatures are stable year-round, meaning ample heat energy is available for utilisation by GSHPs even when air temperatures are very low.

Historically, fuel availability has been a major driver for high heat pump adoption. For example, Sweden, Switzerland and Finland – leaders in the European heat pump market – have little to no access to gas,[100] making heat pumps more attractive than in other gas-connected jurisdictions.

While a handful of European nations are leading on heat pump adoption, other countries are looking to catch up, often driven by an interest in reducing emissions. In Japan, HPHWS that use carbon dioxide as a refrigerant for domestic hot water are increasingly common, with nearly 500,000 of these systems sold in 2018.[101] In 2020, the United Kingdom announced an ambition to dramatically ramp up the annual rate of heat pump installation from its current level of about 35,000 a year[102] to 600,000 each year by 2028.[103] Heat pumps are also a key plank of the United States' plans to decarbonise US building stock.

In nations that have succeeded in driving heat pump adoption, government policy has been crucial. These policies vary from country to country, but often include elements of training and qualification programs for heat pump installers; rigorous design, performance, and maintenance standards and provision of financial incentives to support heat pump adoption.

96 International Energy Agency (IEA) 2020, *Heat pumps – tracking report*, IEA, Paris.

97 Ibid.

98 Ibid.

99 Association of the European Heating Industry (EHI) 2020, *Heating market report 2020*, EHI, Brussels, p. 42.

100 Hanna, R., Parrish, B., and Gross, R. 2016, *Best practice in heat decarbonisation policy*, UK Energy Research Centre, London, p. 16.

101 Hashimoto, K. 2006, *Technology and market development of CO_2 heat pump water heaters (Eco Cute) in Japan*, IEA Heat Pump Centre Newsletter 24(3): 12-16.

102 Lowes, R., Rosenow, J. and Guertler, P. 2020, *Getting on track to net zero: A policy package for a heat pump mass market in the UK*, Regulatory Assistance Project, Brussels.

103 United Kingdom Government 2020, *The ten point plant for a green industrial revolution*, UK Government, London, p. 20.

BOX 15: Global heat pump aspirations

United States

The Biden Administration is pursuing the electrification of buildings as part of its broader emissions reduction effort. The US Department of Energy's Initiative for Better Energy, Emissions and Equity aims to advance the deployment of clean heating and cooling systems, including heat pumps.[104] The initiative includes:

- A nationwide Advanced Water Heating Deployment Initiative to increase market adoption of high-efficiency, grid-connected heat pump water heaters in residential and commercial buildings;
- A Cold Climate Heat Pump Technology Challenge to accelerate performance of cold climate heat pump technologies;
- New collaborative research, development and deployment efforts (RD&D), including partnering national laboratories and manufacturers to accelerate the development of low- to no-GWP refrigerants; and
- New Energy Star standards for central heat pump air conditioners and residential water heaters.

Heat pump RD&D in the US is primarily focused on:

- More efficient cooling/refrigeration systems, including non-traditional cycles;
- Alternative or advanced compression cycle technologies; and
- Lower-GWP refrigerant alternatives.

The United Kingdom Renewable Heat Incentive

In 2014, the UK Government launched the Renewable Heat Incentive (RHI) scheme for residential buildings, which provides financial support to households installing a renewable heating system, including various types of heat pumps, biomass boilers, and solar thermal water heaters.[105] The program had relatively limited success due to significant up-front financial barriers to participation.

In 2020, the UK Government further increased its aspiration around heat pump installations by announcing its plans to deliver 600,000 heat pumps per year by 2028. In October 2021, the UK Government announced a plan for decarbonising buildings by 2050, including grants of up to £5,000 to support heat pump adoption.[106]

104 Vineyard, E. and Baxter, V. 2021, *US heat pump market – 2021 update*, IEA Heat Pumping Technologies TCP, Paris.

105 Ofgem 2021, *Domestic Renewable Heat Incentive (Domestic RHI)*, UK Government, London.

106 Department for Business, Energy and Industrial Strategy 2021, *Heat and buildings strategy*, UK Government, London.

5.3 Challenges

Heat pumps for residential applications are technologically mature and commercially available. However, challenges to the wider adoption of heat pumps in this sector remain.

5.3.1 Information and knowledge barriers

Consumer information barriers

Consultation undertaken for this report highlights that low consumer awareness is a significant barrier to increased uptake of heat pump technology. Interviewees reported that consumers can be:

- Unaware that heat pump technology can perform space and water heating tasks;
- Unaware that existing RCAC appliances can provide heating as well as cooling, with low energy, emissions and operating cost;
- Misinformed about operating costs of appliances, and the relative costs of different fuel types;
- Misinformed about the relative performance of different heating technologies; and
- Provided with advice by retailers, installers or home builders that reflects out-of-date information or conflicts of interest.

Thermal services – particularly water heaters – are frequently considered as part of the building fabric and consumers have little awareness of them on a day-to-day basis. When systems fail, the requirement for urgent replacement often leads to like-for-like replacement, regardless of whether a heat pump appliance may provide lower costs over the lifetime of the appliance.

Further, interviewees reported that a proliferation of poor-quality HPHWS at the start of the 2010s caused significant reputational damage. A 2012 study found that performance claims made by suppliers did not always match actual performance, particularly in cold weather conditions, and suggested methods for performance improvement, including introduction of MEPS.[107] This issue may be inhibiting wider uptake of HPHWS.

Professional information barriers

Equipment suppliers, installers and building professionals play an important role in the deployment of heat pumps, as consumers often rely on these professionals when choosing equipment.

Consultation has highlighted that tradespeople – particularly plumbers – are often unfamiliar with heat pump technology. This represents a challenge for deployment as plumbers often advise consumers on replacement of hot water services, and frequently supply and install equipment. Building professional knowledge – through information, training and certification in heat pump technology – will support plumbers to understand the suitability of HPHWS

107 Equipment Energy Efficiency (E3) 2012, *Product profile: Heat pump water heaters*, Australian Government Department of Industry, Science, Energy and Resources (DISER) and the New South Wales Department of Planning, Industry and Environment, Canberra and Sydney, p. 5-8.

systems for residential applications and provide advice to consumers. A trial is currently underway in Victoria between the Australian Energy Foundation and other stakeholders to engage the plumbing industry to encourage the recommendation of HPHWS to homeowners when they seek hot water system replacements.[108]

Building professionals are also an important target for awareness-raising. Choice of appliances in new homes is often left up to building professionals such as architects, building designers and project managers. Awareness-raising amongst these professions could help to normalise choices of heat pump technology in residential building design.

5.3.2 Financial barriers

Capital cost

Heat pump technology is commercially available from a range of retailers, suppliers and installers. However, the capital cost of heat pump technology is usually higher than resistive electric or natural gas equivalents. At the time of writing, the purchase cost of a HPHWS was approximately 2.5 times that of an equivalent resistive electric or instantaneous gas hot water system.

For space heating, the comparison is less straightforward. The purchase cost of a basic RCAC system starts at around $700 plus installation costs of $600 and up. Larger or more complex heat pump installations – such as ducted or multi-split systems – can range from several thousand dollars to tens of thousands of dollars. Further, heat pump installation requires multiple qualified trades for installation – plumbers, electricians and refrigeration mechanics – which adds to the initial costs of heat pump technology.

Gas space heaters are available for a similar cost, although compared to RCAC, installation costs can be lower if home gas piping is already in place.

Households that choose not to install fixed heating appliances may instead select portable resistive electric heaters, which have a very low upfront cost – as little as $10 – but very high operating costs. While the operating costs and performance of these appliances is not equivalent to heat pumps or other fixed heating appliances, some consumers may be highly sensitive to up-front purchase prices, such as consumers on lower incomes, or disposed to place a high discount factor on future operational savings.

Box 16: Heat pump water heating systems for low-income households

From 2014-2016, the Brotherhood of St Laurence delivered the Home Energy Efficiency Upgrade Program (HEEUP) program[109], which assisted nearly 800 Victorian households to upgrade to more efficient water heating systems. The evaluation found that many households, particularly those with financial constraints, choose like-for-like water heater replacements due to the complexities involved with the purchase process and up-front costs.[110]

The study found that three elements are needed to encourage households to upgrade to a more efficient hot water system, such as a HPHWS:[111]

- Independent information and advice provided through trusted sources;
- A subsidy to assist with capital costs; and
- The offer of a no interest loan.

Economies of scale

While RCAC have achieved significant market penetration and economies of scale, HPHWS have poorer economies of scale for both supply and installation. For example, low demand by consumers means that few plumbers are likely to carry HPHWS as a ready, drop-in replacement, whereas resistive electric and gas appliances are readily available. Relatively low demand and limited competition for HPHWS contributes to their high cost; increased demand for HPHWS would improve economies of scale and encourage suppliers to enter the market, eventually driving down costs.

108 Australian Energy Foundation (AEF) 2021, *Mike Hill Fellowship launches next generation leader in Moreland*, AEF, Melbourne.

109 O'Mullane, L. and Hoch, L. 2016, Home Energy Efficiency Upgrade Program (HEEUP) cost-effectiveness and cost-benefit analyses, in Sullivan, D. 2016, *Home Energy Efficiency Upgrade Program: final report*, Brotherhood of St Laurence, Fitzroy, Victoria, p. 117.

110 Sullivan, D. 2016, *Home Energy Efficiency Upgrade Program: final report*, Brotherhood of St Laurence, Fitzroy, Victoria, p. 148.

111 Byrne, G., Jorgensen, B., Jungbluth, L. and Smith, L. 2016, What was the effect of the Home Energy Efficiency Upgrade Program (HEEUP) on household electricity and gas consumption? in Sullivan, D. 2016, *Home Energy Efficiency Upgrade Program: final report*, Brotherhood of St Laurence, Fitzroy, Victoria, p. 21.

Split incentives

Split incentives can work against the installation of heat pumps in rental homes. Typically, landlords bear the capital costs of building services, such as installation or replacement of water heaters and fixed air-conditioning services, while the operating costs are borne by the tenant. This means that landlords have a financial incentive to install thermal services at the lowest possible capital cost regardless of the operating cost, placing heat pumps at a significant disadvantage.

A similar split incentive exists between builders and purchasers of residential property. Builders, particularly volume home builders, are not exposed to costs of operation, and so may choose heating solutions based on other metrics, such as targeting a low home package price.

5.3.3 Regulatory barriers

Deployment of heat pump technology also continues to face regulatory barriers. In some areas, planning and/or body corporate rules prohibit external ASHP units from being visible from the street. Victorian standards only allow an air-source HPHWS to satisfy requirements for a new 6-star home under very limited conditions[112] and gas-boosted solar systems are preferred – although in its 2022 *Gas Substitution Roadmap*, the Victorian Government has committed to removing these regulatory barriers.[113] A systematic review and action on these sorts of regulatory barriers would make it easier for consumers to choose an all-electric heat pump option.

Installer licencing regimes can also be an issue. Plumbers frequently hold concurrent gas fitting licences, enabling one-stop installation of a gas hot water system. However, completion of all works to install a new HPHWS requires both a plumbing and an electrical licence. Licencing regimes provide important quality and safety controls for consumers, however consideration could be given to streamlining requirements where possible.

5.4 Actions to accelerate heat pump deployment in residential buildings

In the residential buildings sector, the most significant energy and emissions reductions arising from the application of new heat pumps will result from:

- Encouraging building of all-electric new homes, with heat pumps installed for space and water heating;
- Replacing gas heaters and resistive electric heaters for space heating; and
- Replacing resistive electric and gas hot water systems.

This paper identified near term opportunities to accelerate heat pump deployment in five of seven categories (bolded below):

1. **Strategy**;
2. Research and development (R&D);
3. Experience and early deployment, including pilot projects;
4. **Regulation and standards**;
5. **Integration** with renewable energy sources;
6. **Awareness**, including guides, training and campaigns; and
7. **Deployment** at scale, including enabling incentives.

5.4.1 Priority recommendation: Implement a residential building heat pump deployment accelerator program

In the residential sector, significant emissions reduction could be achieved through the development and implementation of deployment programs for RCACs and HPHWS. If developed as a comprehensive suite of measures, a deployment package could overcome a range of barriers to heat pump adoption. This would unlock substantial abatement as the electricity grid decarbonises, as well as supporting healthier and more comfortable homes.

112 Victorian Building Authority 2014, *Solar Heated Water – 6 Star Requirements*, Victorian Government, Melbourne, p.2.

113 Victorian Government 2022, *Gas Substitution Roadmap*, Victorian Government, Melbourne, p.10.

Action

	Activity	Actor
R1	**Develop and implement a heat pump deployment accelerator program for residential buildings, including:** **1. Introduction of E3 labelling and MEPS for HPHWS systems;** **2. Delivery of training and certification for tradespeople in residential heat pump installation;** **3. Awareness and education campaign for households on choosing and maximising benefits from heat pumps;** **4. Establish or expand programs to install heat pumps in low-income and vulnerable households; and** **5. Expand and enhance financial incentives for residential heat pump deployment.** Horizon: 1-5 years Areas: Strategy; Regulation and standards; Awareness; Deployment at scale	Commonwealth States and territories

Development and implementation of a heat pump deployment strategy has the potential to realise significant abatement and bring benefits to households, assuming effective program design. The benefits associated with a residential heat pump deployment program will be maximised if a comprehensive program is delivered.

- **E3 Labelling** and **MEPS** for HPHWS will facilitate informed consumer choice and avoid the risk of poorly performing equipment negating potential benefits.
- **Training** and certification for installers (including plumbers) will ensure better familiarity with the technology and reduce safety, quality and performance risks.
- **Awareness campaigns** can help householders make an informed choice about their heating and cooling equipment and help optimise its performance.
- Programs that fund installation of heat pumps into **public and social housing and vulnerable households** help build market confidence as well as economies of scale, as well as providing healthy, affordable heating and cooling for households that could not otherwise access the technology.
- Widespread **financial incentives** to encourage RCAC and HPHWS uptake in residential buildings will help overcome cost barriers and accelerate deployment.

An integrated, comprehensive government program to deploy heat pumps in residential buildings could overcome multiple barriers at once. For example, a government program to install heat pump technology in a substantial number of low-income and vulnerable households could:

- Provide immediate, firm demand for products, encouraging suppliers to bring products to market;
- Provide an immediate incentive for tradespeople and other professionals to upskill to participate in the program; and
- Provide a strong market for quality appliances, through specification of appropriate minimum product performance to be eligible for the program.

Sub-elements of the recommended program are described in further detail below.

E3 labelling and MEPS

Product standards and energy rating labelling are particularly important in consumer-grade appliances to overcome information barriers. Heat pumps vary in their performance across models and climate zones. Consumers generally do not have the resources to determine which appliance will work best in their climate zone and circumstance, so labels help to ensure that consumers can make an informed choice.

Reverse cycle air conditioners

Reverse cycle air conditioners are regulated by the *Greenhouse and Energy Minimum Standards (GEMS) Act 2012*, which sets out a MEPS. This ensures that appliances meet a basic level of energy performance and effectively removes poorly performing products from the market. More recently, reverse cycle air conditioners have been required to display an updated energy rating label that shows performance in three climate zones (see **Box 17**).[114] This makes the variation in efficiency levels in different climates visible and assists consumers to choose an efficient unit for their climate and circumstances. Continued application of these measures will help maximise the emissions reduction and cost saving benefits to householders and the community from programs that accelerate deployment of RCACs.

Heat pump hot water systems

HPHWS are not currently covered by the GEMS framework. The lack of MEPS or an energy label requirement is a major barrier to unlocking the future energy and emissions savings available from heat pumps. The lack of these instruments means that:

- No mandatory standardised performance testing regime exists for these heaters;
- Consumers lack information on choosing the right appliance for their situation and climate; and
- There is a risk of poorly performing appliances being brought to market, causing both reputational damage and undermining emissions abatement potential. There is some anecdotal evidence that this has already occurred.[115]

Some de facto performance labelling and regulation does exist, as all water heaters eligible for STCs are included on the Clean Energy Regulator's register, which determines how many certificates may be awarded for installing a heater in one of five climate zones. This is based on a performance rating determined under Australian standards related to performance testing of domestic air-source hot water heat pumps – *AS/NZS 5125.1* – and performance calculations under *AS/NZS 4234*. As STCs enumerate expected avoided emissions through deemed energy savings, these provide a crude indication of expected performance, however they presently do not provide a verified measurement of energy usage and do not cover HPWHS that also provide hydronic space heating and cooling. Standardised testing and reporting of performance across HPHWS would be an important prerequisite to deployment of E3 measures.

Implementation of E3 labelling and MEPS is an important prerequisite to a program that accelerates deployment, to ensure that investment in deployment realises the anticipated benefits, and that incentives do not encourage the installation of poorly performing systems.

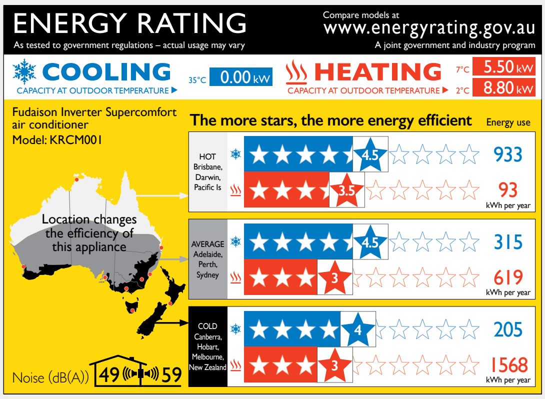
114 Energy Rating 2020, *Air conditioners*, Australian Government Department of Industry, Science, Energy and Resources (DISER) and the New South Wales Department of Planning, Industry and Environment, Canberra and Sydney.

115 Pears, A., and Andrews, G. 2016, *Heat pumps – radical efficiency by moving energy*, Energy Efficiency Council, Melbourne; Harvest Hot Water n.d., *Do heat pump hot water systems work in Canberra?* Harvest Hot Water, Canberra.

BOX 17: Standards and labelling

The Equipment Energy Efficiency (E3) program undertook consultation in 2021 to develop methods for *water heating* to allow consumers to compare across fuel and technology types to assist them to make better informed choices to meet their needs.[116] This work includes the potential for standards and labelling for HPHWS, potentially including MEPS.

The energy rating label for reverse cycle air conditioners has recently been updated to the Zoned Energy Rating Label (ZERL).[117] This new label is a climate-zone based label which indicates the variation in efficiency level for an operating air conditioner, depending on the climate zone in which it's installed. The ZERL approach could also apply to HPWHS in the future.



Source: Energy Rating 2020.

Skills, training, and certification

A skills and training element is an important component of an integrated package to accelerate residential deployment of heat pumps. Appropriately skilled tradespeople will help drive economies of scale, as well as supporting improved quality and safety outcomes and reduce risks of wasted program investment. This would consist of:

- Support for installers to gain necessary mandatory occupational licencing – such as for plumbers to gain required electrical licences. Limitations on the ability of plumbers to offer a 'single-stop' service to replace a gas hot water system with a HPHWS – due to the need for electrical trades licencing – has consistently been raised as a barrier to deployment. Development of training packages to allow a single trade to fully install heat pumps could materially accelerate deployment.
- Heat pump-specific training to build awareness, familiarity and competency with heat pump technology – similar to the EU *Certified Heat Pump Installer Program* (EUCert). Governments and industry bodies could partner to implement training – and potentially certification – for heat pump installers. While this would not be a mandatory occupational licence, eligibility to participate in any government heat pump deployment program would best be restricted to installers that have undertaken this dedicated training – and if deemed necessary, certified – to mitigate against quality and safety risks.

Government support and funding would be important to develop these training packages in a timely fashion.

Awareness campaigns

Targeted awareness-raising and education activities would be an important part of a residential heat pump deployment program. Well-developed communications material could create awareness amongst householders of the overall benefits of using heat pump technology, as well as practical advice on maximising the ongoing benefits of RCAC and HPHWS equipment through optimal use patterns – including integration with onsite solar PV – and periodic maintenance. Awareness-raising supports improving customer demand for heat pump technology, which in turn can drive greater economies of scale. Awareness-raising activities could leverage existing communications channels such as energy.gov.au, state and territory energy-saving websites, as well as bespoke, targeted communications.

116 New Zealand Energy Efficiency & Conservation Authority (EECA) 2021, *Hot water systems*, New Zealand Government, Wellington.

117 Energy Rating 2020, *Understanding the label*, Australian, State and Territory and New Zealand Governments, Canberra and Wellington.

Establish or expand programs to install heat pumps in public housing or vulnerable households

A practical, immediate measure to accelerate heat pump deployment is to directly install heat pump technology – RCACs and HPHWS – into public housing, low-income and vulnerable households at no – or very little – cost to the occupant. These households are likely to realise substantial benefits from introduction of RCAC and HPHWS technology through lower energy bills; access to clean and heathy heating and cooling, and a reduced risk of energy hardship, but are least likely to be able to install them themselves, due to lack of financial capacity, lack of appropriate tenure or inability to make modifications to the property.

A broader range of benefits also comes from these types of programs. By establishing a government-backed program with firm orders for heat pump technology, commercial risk to market participants is reduced, enabling market confidence to grow and building the ecosystem of suppliers, installers and other professionals. In such programs, governments can set eligibility and program requirements to improve outcomes, such as ensuring acceptable quality and performance parameters (such as refrigerant GWP levels or energy efficiency levels) Existing programs, such as the *Victorian Home Heating and Cooling Upgrades* program and the partnership between the ACT Government's Commissioner for Social Housing and retailer ActewAGL, which installs RCAC and other efficient technologies in social and community housing, are good examples of this type of program.

This measure would principally be delivered by state and territory governments, with assistance from the Commonwealth where necessary.

Expand and enhance financial incentives for residential heat pump deployment

For households that have greater financial capacity and ability to make changes to their dwelling, financial incentives can help reduce barriers to uptake. RCACs are currently incentivised through state energy efficiency schemes in Victoria, NSW, the ACT and South Australia. They are also being offered to 250,000 lower-income and vulnerable households through Solar Victoria's Victorian Home Heating and Cooling Upgrades program.

HPHWS for domestic hot water have been eligible for financial incentives through the renewable energy target (RET) scheme since 2001,[118] however the incentives delivered through the RET are scheduled to taper to zero between 2022 and 2030. HPHWS are incentivised through energy efficiency schemes in Victoria, the ACT and South Australia, and are expected to be incentivised in NSW soon. HPHWS are also currently eligible for incentives through Solar Victoria.

Expanding incentives to accelerate the rollout of RCACs will help homeowners justify the upfront capital costs of installation and help expand the contribution that RCACs can make towards Australia's emission reduction goals. Appropriate targeting of incentives – for example, providing the greatest benefit to lower-income households – would support effective use of resources and help build a larger market.

Similarly, considering expanding eligibility of existing incentives to heat pump hot water systems that are used for hydronic heating purposes could accelerate deployment and deliver emissions abatement where emissions-intensive equipment is replaced.

The ecosystem of product suppliers and skilled professionals is less sophisticated for HPHWS. Programs should be proactively designed to build this capacity. Initially focusing on social housing upgrades, followed by programs targeting lower income families, can be an effective way of scaling deployment as the product and service ecosystem matures.

5.4.2 Supporting recommendations

Building codes

Building codes and regulation support improved energy efficiency and emissions reduction in buildings through prescribing minimum requirements for building construction and performance. Building codes, including the NCC and supporting state-based frameworks have direct influence on the choices made in the construction of a new home. Building regulation protects both consumers and the community at large against market failures inherent in construction, including significant information asymmetry between builders and purchasers. A building constructed in 2022 will have a lifespan well beyond 2050, so it is important that new buildings are ready to operate without giving rise to greenhouse gas emissions.

118 Acil Allen Consulting 2019, *Small Scale Technology Certificates: Projections 2019 to 2021*, Clean Energy Regulator, Canberra.

Action

	Activity	Actor
R2	**Align building codes and strategy with a trajectory for net zero-ready buildings, including:** **1. Continuing to advance the NCC and the *Trajectory for low energy buildings* and aligning the NCC to the *Trajectory*; and** **2. Ensure the NCC, NatHERS and BASIX encourage installation of more efficient appliances like heat pumps; and** **3. Remove barriers to heat pumps from building, planning and plumbing regulations.** Horizon: 1-3 years Areas: Strategy; Regulation and standards	Commonwealth States and territories

The *Trajectory for low energy buildings* is a crucial framework for collaborative effort on improved building performance. The *Trajectory* sets a comprehensive roadmap for collaboration between state and federal governments to improve the energy performance of new and existing homes over time. As such, it is an important driver for efforts that support the adoption of more efficient, lower emissions technologies, including heat pumps.

The NCC, NatHERS and BASIX shape the types of appliances that are installed in new homes. Efforts to improve the stringency of these mechanisms will drive more efficient, lower emissions homes and support the deployment of heat pumps.

Building, plumbing and planning regulations have a major influence on the types of equipment installed in new homes, and need to be revised to ensure barriers to heat pump installation are removed. Removing legacy regulations will level the playing field and enable consumer choice, ensuring it is straightforward to build a new home with a HPHWS. Removing barriers to heat pumps in planning regulation – including strata rules – will also facilitate the rollout of heat pumps.

Adopted in 2019, the *Trajectory for low energy buildings*[119] encompasses efforts to improve the energy performance of existing homes and build energy efficient new homes. Both the *Report for achieving low energy homes* and the *Report for achieving low energy existing homes* acknowledge the need for low energy homes to provide low energy bills, save energy, improve comfort levels, and reduce carbon emissions.[120, 121]

Further support for the *Trajectory* and ensuring the NCC aligns to the *Trajectory*, are key enablers for heat pump deployment. State-based building regulations should align with the *Trajectory* to encourage net zero-ready buildings. Existing regulations that create barriers to installation of low-emissions technology should also be reconsidered, in line with the *Trajectory*.

Revision of planning regulations – including strata or owners' corporation rules – that prohibit or create substantial barriers to the installation of heat pumps would also be a key action to facilitate deployment of heat pumps for residential buildings.

Overcoming property market failures

Information asymmetry, split incentives, and lack of agency in the property market are barriers to investment in efficient technology like heat pumps. Government programs can help overcome these market failures.

Action

	Activity	Actor
R3	**Introduce schemes to mitigate market failures in the property market that act as barriers to installation of heat pump technology, including:** **1. Mandatory disclosure of energy efficiency performance at point of sale and lease for residential homes; and** **2. Minimum standards for residential rental properties.** Horizon: 1-3 years Areas: Strategy; Regulation and standards	Commonwealth States and territories

Increasing transparency around energy performance through mandatory energy performance disclosure will create an incentive for builders to install more efficient appliances in homes, and allow people selling their home to capture the value of upgrading space heating and water heating to more efficient equipment.

Minimum rental standards recognise the need to provide basic consumer protections to tenants who live in inefficient rental homes and can't demand energy efficiency upgrades without risking eviction.

Minimum rental standards could encourage the installation of heat pumps for space heating and cooling, and water heating in rental properties. This would help ensure all homes meet basic health and safety requirements while reducing costs and emissions associated with space heating and cooling, and water heating in rental properties.

119 Council of Australian Governments (COAG) Energy Council 2019, *Report for achieving low energy existing homes*, Commonwealth of Australia, Canberra, p. v.

120 Council of Australian Governments (COAG) Energy Council 2019, *Report for achieving low energy existing homes*, Commonwealth of Australia, Canberra, p. 9.

121 Council of Australian Governments (COAG) Energy Council 2018, *Report for achieving low energy homes*, Commonwealth of Australia, Canberra.

The Australian Government's Commercial Building Disclosure (CBD) program has demonstrated the effectiveness of requiring disclosure of energy performance prior to lease or sale. Extension of mandatory building disclosure to residential buildings would assist home buyers to overcome information asymmetry during purchase. This would also help to reduce potential split incentives when installing heating equipment, as efficient thermal equipment could add to a buyer's perception of value. Work is underway under the *Trajectory* to introduce a national energy efficiency disclosure framework to enable home buyers to compare the efficiency of homes on the market.

Minimum standards for rental homes are an important component of overcoming split incentives and market power imbalances in the rental housing market. Where landlords seek to minimise capital outlay for building services and fabric, tenants shoulder higher ongoing operating costs. Improving the quality of rental housing, including through encouraging heat pump technology that can provide thermal services for tenants at low operating costs, can provide multiple economic and health benefits for both tenants and the community at large.

Ongoing policy development

Integration of residential heat pump technology with renewable energy sources

In residential settings, a very rapid scale up of heat pumps presents some challenges, but also major opportunities. A wholesale transition to heat pumps which did not seek to align their electricity use with the availability of renewable electricity could exacerbate challenges in Australia's electricity grid, particularly in the early evening. However, proactively pairing heat pumps with solar PV is a major opportunity to reduce pressure on the grid, and provide heating and cooling to households at near-zero operating cost and emissions.

Action

	Activity	Actor
R4	**Develop and implement a framework to optimally integrate heat pumps with the decarbonising electricity grid, including R&D, standards and platforms for market participation.** Horizon: 1-3 years Areas: Strategy; Integration with renewable energy	Commonwealth

Work with researchers, industry, and energy market stakeholders to rapidly develop policies that support integration of flexible heat pumps into the electricity market. Efforts should focus on maximising the ability of heat pumps to utilise renewable energy at times of most abundance, and apply demand flexibility through grid-wide aggregation of residential heat pump load.

ACTION

Opportunities include:

- Programming HPHWS to heat water when renewable energy availability is greatest, and store hot water for later use, effectively functioning as a thermal battery; and
- Programming RCACs to heat or cool an indoor space when renewable availability is greatest – provided the building is well sealed and insulated – to reduce the need for heating or cooling across greater temperature differentials later and when grid demand is higher.

These are relatively simple mechanisms for demand flexibility that require little in the way of advanced grid architecture or inconvenient behaviour changes from householders.

More sophisticated grid integration for heat pumps could provide opportunities to further increase emissions savings in response to grid-based market signals. RCACs and HPHWS can be enabled to respond to these signals, for example by becoming demand-response enabled. Demand response enabled devices (DRED) have the ability to respond to signals to reduce pressure on the electricity grid when demand is high, for example by switching appliances off or to a lower-power mode for a short period of time.

There has been some momentum in Australia around requiring DRED for reverse cycle air conditioners – particularly with Queensland's PeakSmart program[122] – however there is more work to do, and any requirements should be based on modern, internationally recognised standards. Although the PeakSmart program was initially also intended to cover hot water systems, these appliances are instead managed through controlled-supply tariffs that only provide power to appliances outside of peak times. The extent of market penetration for DRED in HPHWS is unclear, and given the generally low power requirements of domestic HPHWS, the benefits of deployment may not outweigh the costs.[123]

There is a limited window for development of strategic policy and coordination to unlock the benefits of integrating heat pumps into the decarbonising electricity grid. Setting appropriate integration frameworks in place at an early stage will help capture maximum value from the combination of renewable energy and heat pumps throughout a transition to net zero. Important objectives include:

- Rapid R&D to determine optimal and scaled alignment of heat pumps with renewable energy sources;
- Protocols and standards to aggregate and load-manage RCAC, and utilise HPHWS at the most optimal times (typically in the middle of the day); and
- Development of aggregation platforms that facilitate the participation of demand response enabled devices in the NEM and the Wholesale Electricity Market (WEM).

Strong support from governments and active translation of lessons learnt into policy and regulations will be important to facilitate a smooth scale up of heat pumps in the market.

BOX 18: International innovation in demand response

At the European Union (EU)-level, the **smart readiness indicator (SRI)** – an indication of a building's ability to optimise energy efficiency, adapt operation to occupant needs, and adapt to signals from the electricity grid – has been developed to raise awareness of the benefits of smart building technologies.[124] The EU has developed the SRI as part of its commitment to modernise its building sector and increase the rate of building retrofit with the expectation of supporting technology innovation in the buildings sector.

The California Energy Commission recently developed the Market Informed Demand Automation Server (MIDAS).[125] This is a database of current and future time-varying electricity rates, emissions associated with electricity generation, and 'FlexAlert' signals – calls to consumers to voluntarily reduce energy consumption to reduce stress on the grid. The sophisticated database supports California's electrification goals by enabling devices to access a range of load flexibility signals so that electricity supply and demand can be matched.

122 Department of Climate Change, Energy, the Environment and Water (DCCEEW) n.d., *Energy-efficient air conditioning incentive – Energex*, Australian Government, Canberra.

123 Department of Environment and Energy 2019, *Regulation impact statement for decision: 'smart' demand response capabilities for selected appliances*, Australian Government, Canberra.

124 European Commission 2021, *SRI Explained*, European Commission, Brussels.

125 California Energy Commission 2021, *Staff webinar Market Informed Demand Automation Server (MIDAS)*, California Energy Commission, Sacramento.

Residential retrofits

All new homes built in Australia must rate a minimum of 6 stars under the National House Energy Rating Scheme (NatHERS), however, most of the country's nine million existing homes rate below 3 stars.[126] Developing a national plan to bring these homes up to the current, minimum standard could improve health and safety and reduce energy consumption and emissions. Improving the thermal efficiency of homes would unlock multiple benefits for their inhabitants and the community, including reducing transition and grid costs by more closely matching energy usage with low-cost, low-emissions energy.

While the *Trajectory* covers both new and existing buildings, retrofitting Australia's existing building stock to be 'net zero-ready' is a massive task and warrants additional strategic effort. An ambitious plan to retrofit existing homes, using a variety of policy levers, could make a substantial contribution to reducing energy usage and operational emissions from existing residential buildings. A retrofit strategy could also consider opportunities to phase out emissions-intensive appliances in existing residential buildings, including revisiting the 2010 agreement for a staged phase out of resistive electric hot water systems that were considered 'greenhouse-intensive'.[127]

Action

	Activity	Actor
R5	**Develop a comprehensive national residential retrofit strategy.** Horizon: 1-3 years Areas: Strategy	Commonwealth

126 Council of Australian Governments (COAG) Energy Council 2019, *Trajectory for low energy buildings – Existing buildings*, Commonwealth of Australia, Canberra, p. 3.

127 Department of Climate Change and Energy Efficiency 2010, *Phase-out of greenhouse intensive hot water systems*, Australian Government, Canberra.

6

The opportunity in commercial buildings

Summary

- Heat pump deployment in commercial buildings could **save from 377 to 1677 PJ and 21 to 96 Mt CO_2e** by 2050.
- The **greatest potential for abatement is in retrofits of existing buildings**, but new buildings can benefit by adopting heat pump technology as well.
- Heat pump technology for **commercial buildings is relatively mature**, but barriers to adoption exist in market readiness and experience.
- **Rapid knowledge and experience-sharing** could overcome barriers to heat pump adoption for commercial buildings.
- A range of options exist to **stimulate demand** and help create market familiarity and economies of scale for heat pump adoption.

6.1 Sector overview

Heat pumps already provide thermal energy services in the Australian commercial buildings sector – most commonly for space cooling – but there is significant potential to expand their application to provide low-cost, net zero emissions space and water heating. The *Heat Pump Energy and Emissions Savings Model* projects that cumulative emissions abatement to 2050 of up to 96 Mt CO_2e and energy savings of up to 1,677 PJ could be available through rapid deployment of heat pump technology – see **Table 11**, although actual rates of heat pump deployment in existing commercial buildings could be influenced by various constraints.

Heat pump penetration scenario	Cumulative energy savings to 2050 (PJ)	Cumulative greenhouse gas emission savings to 2050 compared to baseline ($MtCO_2e$)	
		AEMO 'Central'	AEMO 'Step change'
Late adoption, 100% deployment 2040-2050	377	21	22
Linear to net zero 2050 (3.3% p.a.)	1031	56	59
Linear to net zero 2050 + extra efficiency (+2.1%)	1332	83	79
Supercharged deployment to 100% in 10 years (10% p.a.)	1677	90	96

Table 11 Commercial buildings sector results from the *Heat Pump Energy and Emissions Savings*

BOX 19: Commercial buildings – building types

The term 'commercial building' covers many types of property: from large CBD office towers to small retail shops in country towns, and everything in-between. How these diverse buildings use energy is shaped by many variables including use, access to affordable energy sources, and the value of space. The sheer range of variables make generalisations about opportunities for heat pump uptake challenging.

Larger buildings, with centralised plantrooms and access to gas are more likely have gas boilers for heating. Smaller buildings, where the distance between the conditioned space and outside allows, are more likely to use a Variable Refrigerant Flow (VRF) system – a reversible heat pump for heating and cooling.

In this report, the term 'large buildings' refers to those with central plantrooms. Small commercial buildings are more commonly served by decentralised HVAC systems.

This section focuses on the three most significant energy and emissions reduction opportunities arising from the application of new heat pumps in commercial buildings:

- Encouraging the use of heat pumps for heating load in new buildings;
- Replacing gas boilers that provide space heating, especially in large commercial buildings; and
- Replacing electric resistance and gas hot water systems, especially in large commercial buildings.

The ambitious commitments set by many Australian property groups to achieving net zero operational emissions in their properties by at least 2030 – and in some cases by 2025 – could be a strong market driver for the shift to heat pumps for heating in Australia's commercial building sector.[128] For the property sector, electrification of heating load is regarded as one of the primary tools for achieving these goals.[129]

Much of the technology to deploy heat pumps in commercial buildings is commercially mature and readily available, especially in smaller buildings – see **Figure 20**. However, utilising heat pumps for centralised heating in large commercial buildings remains uncommon around the world, even in new buildings. Further, research undertaken for this report has not identified any examples of retrofits of existing buildings in Australia that had replaced gas boilers with heat pumps.

This means supply chains for these applications are embryonic, and professionals have not had the opportunity to develop skills and experience in the design, installation and commissioning of heat pump systems in larger commercial buildings.

Pilot projects would help quickly develop and disseminate knowledge among relevant building design professions and trades. Enhanced experience and skills amongst professions and consultancies will also help commercial building owners develop a comprehensive business case for heat pump adoption. Existing strategic policy such as the *Trajectory for Low Energy Buildings*, the National Construction Code (NCC) and the Commercial Building Disclosure (CBD) program are also important tools that can be harnessed to support heat pump adoption.

128 For example, see Growthpoint Properties 2021, *Growthpoint targets net zero by 2025*, Growthpoint Properties, Melbourne; *GPT Group 2020, GPT managed assets to become carbon neutral by 2024*, GPT Group, Sydney; Mirvac 2021, *Mirvac hits net positive target nine years early*, Mirvac, Sydney.

129 Beyond Zero Emissions 2013, *Zero carbon Australia buildings plan*, Melbourne Energy Institute, Melbourne, p.3; Nadel, S. and Perry, C. 2020, *Electrifying space heating in existing commercial buildings: opportunities and challenges*, American Council for an Efficiency Economy (ACEEE), Washington, DC.

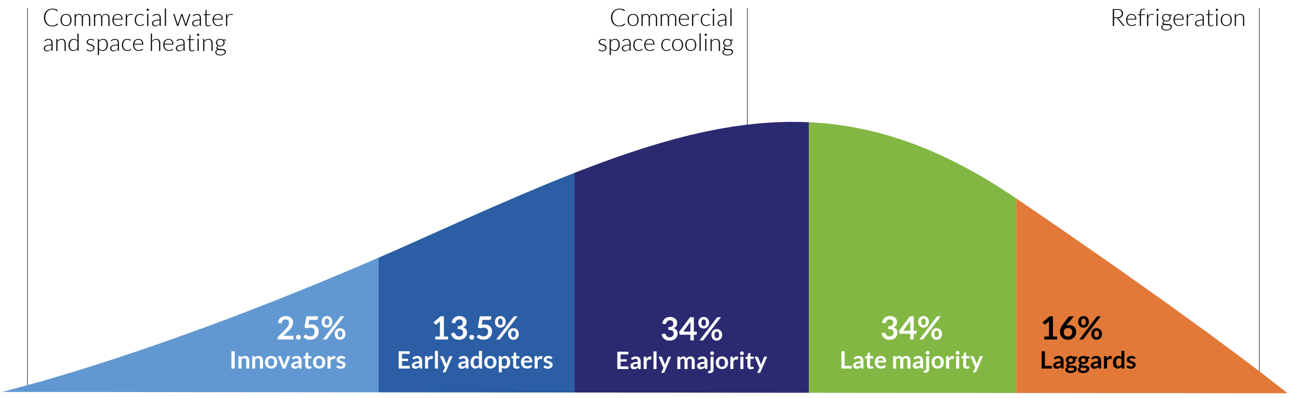


Figure 20 Estimated adoption level for heat pump technologies in commercial buildings

Prompt action on this front is important. Electrification of existing heating systems takes advanced planning, and decisions made around system installations can lock buildings into a chosen fuel for years.

Gas boilers and water heating systems typically operate over a lifetime of up to 25 years.[130, 131] This means that there is, on average, less than two system lifetime cycles for gas-fuelled systems that are installed or replaced between now and 2050. If heat pumps are to contribute substantially to 2050 net zero goals in the commercial building sector, early action is needed to prime the market to realise the transition. A priority recommendation for action to accelerate heat pump deployment in commercial buildings is shown in **Table 12**.

	Activity	Actor
C1	**Fund a major new ARENA program to pilot and demonstrate heat pump retrofit projects in larger commercial buildings.** Horizon: 1-5 years Areas: Experience and early deployment; Awareness	Commonwealth

Table 12 Priority recommendation for driving the adoption of heat pumps in commercial buildings

130 Nadel, S. and Perry, C. 2020, *Electrifying space heating in existing commercial buildings: opportunities and challenges*, American Council for an Efficiency Economy (ACEEE), Washington, DC, p.77.

131 US Department of Energy (DOE) 2016, *Energy conservation program: Energy conservation standards for commercial water heating equipment*, DOE, Washington, DC, p. 174.

6.2 Heat pump applications and opportunities in commercial buildings

Using heat pumps for space cooling in large commercial buildings is the industry standard around the world, with market penetration at or nearing 100%. However, the use of heat pumps for heating in large commercial buildings with centralised plant rooms remains very rare; commercial-sized heat pumps (with a heating capacity of greater than 50 kW) make up a small proportion of the international heat pump market.[132]

Heat pumps are more common for space and water heating in small- and mid-sized commercial buildings, often utilising products that are the same or similar to those used in residential buildings.

6.2.1 Australian opportunities

Heating, ventilation and air conditioning (HVAC) accounts for up to 50% of energy costs in commercial buildings.[133] This means that HVAC equipment upgrades present a significant opportunity for emissions reduction in the commercial building sector, particularly when combined with building envelope upgrades, which can reduce energy requirements for space heating and cooling.

Supporting installation of heat pumps for heating in leading edge new commercial buildings will help build skills and supply chains. However, Australia's building stock turns over slowly, which means the greatest opportunity identified for heat pumps in commercial buildings is in the retrofit of existing buildings.

Table 13 shows the current estimated level of deployment of heat pump technology in different types of commercial buildings. Deploying heat pumps in large Australian commercial buildings presents a particular opportunity for innovation and leadership.

Building type	Water heating	Space heating	Space cooling	Pool heating	Refrigeration
Shopping centres	Low	Low	High	N/A	High
Office	Low	Low	High	N/A	High
Healthcare	Low	Low	High	Low	High
Schools	Low	Low	High	Low	High
Data centres	Low	N/A	High	N/A	High
Hotels (accommodation)	Low	Med	High	Low	High
Retirement/aged living	Low	Med	High	Low	High
University	Low	Low	High	Low	High
Apartment buildings (common areas/services)	Low	Med	High	Low	High

Table 13 Heat pump market penetration in the delivery of common thermal energy services – commercial buildings

132 Eunomia Research & Consulting 2020, *Heat pump manufacturing supply chain research project final report*, UK Department for Business, Energy & Industrial Strategy, London, p. 37.

133 Department of Industry, Science, Energy and Resources (DISER) 2021, *HVAC*, Australian Government, Canberra.

Applications for heat pump technology in commercial buildings

As in residential buildings, the requirement for thermal energy services varies by climate zone. Warmer climates have less need for space heating – see **Table 14**. The market demand for various thermal energy services across Australia's climate zones – coupled with market penetration of heat pumps in delivering these services – suggests a number of areas in which heat pumps could play an important role:

- Space heating in all property types, especially climate zones 4-8;
- Pool heating, especially in climate zones 4-8; and
- Domestic hot water in all property types in all climate zones.

Climate zone	Water heating	Pool heating	Space heating	Space cooling	Refrigeration
Climate zone 1: Hot humid summer, warm winter	High	Low	Low	High	High
Climate zone 2: Warm humid summer, mild winter	High	Low	Low	High	High
Climate zone 3: Hot dry summer, warm winter	High	Low	Low	High	High
Climate zone 4: Hot dry summer, cool winter	High	Med	Med	High	High
Climate zone 5: Warm temperate	High	Med	Med	High	High
Climate zone 6: Mild temperate	High	Med	Med	High	High
Climate zone 7: Cool temperate	High	High	High	Med	High
Climate zone 8: Alpine	High	High	High	Med	High

Table 14 Typical demand for common thermal energy services across climate zones – commercial buildings

For water heating, interviews and desktop research undertaken for this report has found that heat pumps have a relatively high commercial maturity for small-to-medium commercial buildings, but lower for large buildings. There were 2,200 heat pumps for commercial hot water applications installed in 2018,[134] a small percentage of overall market share.

Heat pumps for space heating in small buildings were found to have a relatively high commercial maturity due to overlap in the market for residential units. However commercial maturity was found to be significantly lower for these applications in large buildings.

134 Brodribb, P., and McCann, M. 2019, *Cold Hard Facts 2019*, Department of the Environment and Energy, Canberra, p. 11.

Retrofit opportunities

The opportunity for heat pump retrofits in existing commercial buildings fitted with gas or electric resistive heaters is significantly larger than new builds; indeed, most of the large commercial buildings that will exist in 2050 have already been built. Development of a mature commercial ecosystem for retrofitting heat pumps into existing buildings is crucial to realise the energy and emissions savings opportunity in commercial buildings.

Retrofit challenges

Retrofit opportunities in commercial buildings will vary from a relatively simple swap-out of individual space or water heaters where space and infrastructure allow, to much more complex retrofits in buildings with a centralised plantroom, complicated heating and cooling requirements and little space or infrastructure to vary the current equipment configuration.

Experts consulted for this report have noted that integration of heat pump technology into existing large commercial buildings can impose a new set of requirements. These requirements can include access to ventilation – for ASHPs – new piping to deliver refrigerant around the building – for VRF systems – upgrades to electrical infrastructure and building management systems, as well as additional space to house larger equipment. In particular, heat pump systems can take up considerably more space compared to a similarly sized gas boiler system, which may not be readily available without building modifications.

An overarching challenge is that such retrofits are entirely novel in Australia, meaning that early adopters need to address the integration issues outlined above without any prior experience to draw on. Given the relative homogeneity of services and applications in the commercial building sector, it is reasonable to expect that the lessons learned from pilot projects could be readily adopted across the sector, building confidence and lowering the costs of adoption.

Indeed, the view of interviewees was that none of these challenges are insurmountable; rather, they need to be acknowledged so that industry and government can work together to overcome them.

Gas boiler replacement

Commonly used to heat water for space heating in large commercial buildings, gas boilers can be replaced with air-, ground- or water-source heat pumps.

The most efficient condensing gas boilers have a COP of around 0.95; older boilers often have a COP of around 0.8. This means replacing a boiler with a heat pump can more than triple the COP. Further, fuel-switching to electricity provides the opportunity to harness renewable energy to power the heat pump, leading to potential emissions savings. However, the economics of replacing conventional gas boilers with heat pumps in existing buildings is highly site-specific, depending on access to electricity, space, building thermal requirements and ready access to a heat source – air, ground or water.[135]

Retrofitting heat pumps to replace gas boiler systems is on the agenda of some commercial building owners. Interviewees consulted for this report said that challenges related to pre-existing building design have delayed pilot projects.

Domestic hot water

Replacing gas and resistive electric systems with heat pump domestic hot water systems – typically ASHP – can be relatively straightforward in commercial buildings, provided a well-ventilated location is available. However, such ventilation isn't always readily available in basements or other internal areas of a building. Heat pump systems may also require additional space for thermal storage tanks that smooth demand and reduce the size and capital cost of heat pumps.

Choice of hot water system depends on similar considerations to space heating, with many commercial buildings relying on distributed systems located near the point of use. This can result in a high quantity of smaller hot water systems in retail kitchens, office kitchenettes, bathrooms and end-of-trip facilities. While the energy demand for individual hot water systems is small, the high number of units and daily need for hot water means the overall energy demand can be significant.

135 Nadel, S. and Perry, C. 2020, *Electrifying space heating in existing commercial buildings: opportunities and challenges*, American Council for an Efficiency Economy (ACEEE), Washington, DC, p. 57.

BOX 20: Heat pump hot water retrofit in a mid-size commercial building

When the Crows Nest Community Centre (CNCC) was looking to upgrade the building's ageing gas hot water system, a heat pump system was selected for its high efficiency and ability to run on renewable energy. Four 7.2kW air-source heat pumps – see **Figure 21** – plus two 420-litre storage tanks were installed, replacing three gas boilers which provided approximately 357,000 litres of hot water annually.[136]

The replacement resulted in estimated annual energy savings of 31,514 kWh and $6,302 in annual energy cost savings. The installation received 66 Small-scale Technology Certificates as part of the Australian Government's Renewable Energy Target. The system runs on the electricity generated by CNCC's 30.5kW rooftop solar PV system and is expected to save 90 tonnes of carbon dioxide over its 15-year lifetime.

It is a scalable system, installing as many storage tanks and heat pump units as needed to service the building.

Figure 21 CNCC's heat pumps and storage tanks

Integrated retrofit opportunities

Heat recovery is a method of capturing waste heat and utilising it to re-heat a medium, such as air or water. Heat recovery could play a role in large commercial buildings, by using heat pumps to recover heat from a range of sources – such as the waste heat from refrigeration, server rooms and data centres, or heat-recovery ventilation. In climates where demand for space cooling is dominant, waste heat rejected from air conditioning systems can be recovered to provide water heating services.

Heat recovery systems can boost overall system efficiency by recycling heat and reducing overall thermal energy demand. Using recycled heat can also improve heat pump efficiency by reducing the temperature lift required of the heat pump, which improves the coefficient of performance of the system.

Deployment of heat pump technology in commercial buildings can also be combined with other efficiency measures, such as improvements to building thermal envelopes and fabric and changes to HVAC system design to take full advantage of flexible heat pump operation.

As well as additional energy and emissions savings, an integrated approach has another potential co-benefit: lowering thermal energy requirements through cost effective efficiency measures can reduce the size and capacity of required heat pumps, lowering capital costs.

An integrated approach to retrofits, while ideal, can add further complexity to what many building owners and managers will already regard as a complex project. It may not be feasible in the short term. However, these opportunities should be kept in focus as the market gains experience and comfort with heat pump technologies.

136 NSW Department of Planning and Environment n.d., *Hot water case study: Commercial heat pump hot water system*, NSW Government, Sydney.

New building opportunities

Integration of heat pumps in new, all-electric large commercial buildings has few of the challenges associated with retrofits. New buildings can take advantage of the full suite of low-emissions thermal services technology through integrated design of heat pump-provided water heating and space conditioning, high-performance building shell and fabric, smart energy services and renewable energy. Indeed, pursuing an all-electric design at the outset can prevent future challenges associated with heat pump retrofit, including space limitations, airflow requirements, and noise.

Interviewees indicated that premium property groups have begun requesting designs for new, all-electric large commercial buildings in the last 2-3 years. These designs invariably rely on heat pumps for a range of applications. However, interviewees indicated that none of these projects have reached the construction phase in the commercial sector; some interviewees indicating that construction has been delayed due to COVID-19. As a result, the building design professionals responding to these requests have developed a theoretical understanding of large heat pump systems for space heating, but not the practical experience of their application.

One notable exception is the Canberra Hospital Expansion, which the ACT Government has committed will be 100% electric.[137] At the time of writing, construction on this project is underway and will provide valuable insights on real world heat pump applications in a large, complex commercial building.

137 ACT Government 2020, *ACT Government announces first all-electric public hospital in Australia (if not the world)*, ACT Government, Canberra.

BOX 21: Heat pumps for aquatic centres

Aquatic centres are high energy consumers when compared with other commercial building types. While there are relatively few of them – approximately 1,900 across Australia[138] – they can consume up to seven times as much energy per square metre as other types of commercial buildings[139] due to the combination of pool and space heating, water evaporation, continuous ventilation and poor thermal efficiency. Despite aquatic centres being large energy users, there is very little data publicly available on their total energy usage, the heating technologies used, or the total energy costs for the sector.

Most aquatic centres rely on gas boilers to control indoor air and pool water temperature. Pool water and the surrounding air are heated, the pool water evaporates, and ventilation fans remove the resulting hot, steamy air. This removal of heat necessitates the ongoing heating of air and water. In cooler climate zones, this process consumes very large volumes of gas. Replacing these boilers with highly efficient heat pumps – which can capture and recycle waste heat – coupled with building envelope improvements, can slash energy consumption and emissions while reducing financial pressure on councils.

More than one in six local councils in Australia have made net zero commitments,[140] which is motivating efforts to reduce consumption of gas and increase electrification, including installation of heat pumps. Recent gas price increases and volatility have added to the focus. However early efforts on this front are rapidly revealing how much support the aquatic centre sector needs to decarbonise, particularly as aquatic centres often represent local councils' largest source of energy spend and emissions.[141]

The **Northcote Aquatic and Recreation Centre** redevelopment – see **Figure 22** -is pursuing an all-electric, net zero emissions redesign in line with Darebin City Council's long-term vision for net zero emissions.[142]With maintenance costs of the previous facility expected to reach over $3 million annually, the Council decided to embark on a rebuild including the installation of air-source heat pumps for space heating and cooling, and water heating. The rebuild will also include an airtight building façade to minimise heat loss, heat recovery ventilation to capture and re-use waste heat, rooftop solar and battery storage. Upon completion, it will be the first all-electric aquatic centre in Victoria.[143]

Figure 22 Northcote Aquatic and Recreation Centre

138 Duverge, J. 2019, *Energy performance and water usage of aquatic centres*, Dissertation, RMIT University, Melbourne.

139 Ibid.

140 Cities Power Partnership 2021, *Net zero: how are Australian councils playing their part?,* Cities Power Partnership, Melbourne.

141 Australian Renewable Energy Agency (ARENA) 2021, *Brimbank aquatic and wellness centre integrated energy system*, ARENA, Canberra.

142 City of Darebin 2021, *Find answers to our frequently asked questions relating to the proposed new facility*, City of Darebin, Melbourne.

143 Green Building Council Australia (GBCA) 2021, *Northcote Aquatic and Recreation Centre*, GBCA, Sydney.

Technology to watch: variable refrigerant flow

Variable refrigerant flow (VRF) systems – also called variable refrigerant volume systems – are increasing penetration in small-to-medium size commercial buildings. Similar to multi-head split systems, VRF systems connect multiple indoor units to a single outdoor unit. VRF systems incorporate networked control, as well as distribution joints and headers to effectively deliver space heating and cooling to separate zones.[144]

VRF could make it easier to deploy heat pumps in commercial buildings, both in new designs and retrofits. These systems avoid the complexity of large central plantrooms, the management and servicing that it requires.

VRF systems have relatively high technological maturity, with commercial maturity improving overseas. VRF systems have typically been used in small commercial buildings, but are finding application in some countries – such as Japan – with increasingly larger buildings. As commercial maturity for larger applications improves, VRF systems may become a technology of choice in commercial buildings.

BOX 22: Retrofit of space heating and cooling in an aged care facility

When a Canberra aged care facility reviewed their energy savings opportunities, a consultant presented three options for a space heating and cooling system upgrade for a system with 500kW of cooling and 560kW heating capacity. The options included:

- A constant speed 4-Pipe Heat Recovery Chiller System;
- A combination chiller/boiler system; and
- A variable refrigerant volume (VRV) system with heat recovery.

Table 15 summarises the capital outlay for each system, the estimated annual energy costs, and annual energy and emissions savings. The VRV system had the lowest projected capital outlay, annual operating costs, energy consumption and emissions. Over a 20-year operating lifetime, the VRV system would save $662,881 compared to the heat recovery chiller.

	Budgetary Capital Cost ($)	Annual Energy Cost ($)	Annual Electricity Consumption (kWh)	Annual Gas Consumption (MJ)	Annual Energy Consumption (GJ)	Annual GHG Emissions (Tonnes CO_2e)
Heat Recovery Chiller System	$306,400	$114,484	618,835	–	2,228	514
Chiller/Boiler System	$255,500	$148,105	103,921	5,155,193	5,529	351
VRV System	$200,000	$71,186	384,787	–	1,385	319

Table 15 Three options for space heating and cooling at an aged care facility

Source: Applied Energy Saving Solutions 2020.'

144 Carrier Corporation 2013, *Variable refrigerant flow systems*, Carrier, Syracuse, NY.

Market drivers

There are a range of market drivers that are increasing interest in heat pump applications including electrification, efficiency, and operational cost savings. As of 2019, 43% of leading Australian property companies had set a net zero before 2050 target or aspiration.[145] This percentage has been increasing, with property companies such as ISPT making new commitments and others strengthening commitments since the release of the ClimateWorks Australia Net Zero Momentum Tracker for Property report.[146] For example, Stockland Corporation has brought its net zero emissions target forward to 2028 from 2030,[147] and in 2021 Goodman Group achieved carbon neutrality in its global operations ahead of its 2025 target.[148]

For the growing number of commercial property owners that are seeking net zero operational emissions in their portfolios, electrification is regarded as the next step towards realising these aspirations. For buildings being constructed in the 2020s, designing heating systems that can take advantage of renewable energy can prevent fossil-fuel lock-in, and enable building owners to align themselves with the global community's aspirations to reach net zero by 2050.

6.2.2 Global trends

The installation of heat pumps for space heating in commercial buildings has gained traction in some specific areas. In Japan, variable refrigerant flow (VRF) systems have become more popular, with these multi-zone reverse cycle air conditioners being installed in increasingly larger commercial buildings. In China, ground-source heat pumps (GSHPs) are installed widely in public buildings with central heating demand – see **Box 24**.[149] In Sweden, heat pumps are increasingly being introduced in commercial buildings that are connected to district heating systems.[150]

While many nations have identified the crucial role of heat pumps for decarbonising commercial building heating load, no country has achieved a mature stage of commercial application of centralised heat pumps in large commercial buildings.

This presents an opportunity for Australia, which boasts some of the most sophisticated property groups in the world when it comes to energy performance management. With our electricity grid rapidly decarbonising, Australia has the opportunity to spearhead the global effort to build the knowledge, skills and supply chains we need to electrify heating processes within commercial buildings.

BOX 23: Growing the demand for heat pumps in commercial buildings in the UK

The majority of buildings in the United Kingdom utilise gas for space heating. The UK Government is actively pursuing measures to move away from gas in pursuit of net zero targets, and recognises that heat pumps offer solutions in many applications.

Consultation on the *Future Buildings Standard* commenced in January 2021 to align energy efficiency standards in buildings with the UK Government's net zero emissions by 2050 target. It is expected that most commercial buildings in the UK – specifically those with space heating demand suitable for heat pumps and water heating demand partially suitable for heat pumps – "should be ready to adopt heat pumps or other forms of low-carbon space heating in 2025."

145 ClimateWorks Australia 2019, *Net Zero Momentum Tracker: Property Sector report*, ClimateWorks Australia, Melbourne.

146 ClimateWorks Australia 2021, *Net Zero Momentum Tracker: Commitments – Property*, ClimateWorks Australia, Melbourne.

147 Stockland 2021, *Stockland accelerates Net Zero Carbon commitment to 2028*, Stockland, Sydney.

148 Goodman 2021, *Goodman achieves global carbon neutrality ahead of 2025 target*, Goodman, Sydney.

149 Yang, L. 2020, *Heat pump market development in China*, IEA Heat Pumping Technologies Magazine 39(3): 14-17.

150 Averfalk, H., Ingvarsson, P., Persson, U., Gong, M., and Werner, S. 2017, *Large heat pumps in Swedish district heating systems*, Renewable and Sustainable Energy Reviews 79: 1275-1284.

6.3 Challenges

6.3.1 Market maturity

While heat pumps for residential and small commercial buildings are readily available as off-the-shelf systems, more complex design and integration into new buildings and retrofits suffers from a lack of experience in the market.

Skills

Australia has a highly skilled professional community that undertakes design, installation, and maintenance for conventional HVAC systems. However, these professionals often have limited or no experience in heat pump equipment for novel applications such as space heating in large commercial buildings.

The immediate skills gaps for the installation of heat pumps in new buildings and the retrofit of heat pumps in existing buildings include:

- System design, specification, modelling and costing;
- Installation of heat pump systems; and
- Commissioning.

These gaps pose a particular challenge in large commercial buildings.

In new, large commercial buildings, expertise is developing in the consultancies assisting ambitious clients, but it is at a nascent stage. The broader community of building design professionals is largely unfamiliar with the general theory around large heat pump systems, and experience designing them – including modelling, equipment selection, and ensuring performance on worst condition days – is virtually non-existent.

There are similar challenges when it comes to retrofits, with the additional complexity of integrating heat pumps into an existing building design. Typically, replacing a gas boiler with a heat pump will require consideration of a series of factors – such as appropriate system capacity and ability to integrate with other systems, sound, ventilation and electrical requirements – which are not material when replacing a gas boiler like-for-like. As replacements often occur when a gas boiler fails and must happen quickly, path dependency – including familiarity, prompt access to 'drop-in' solutions, and low technical and financial risk – can lead engineers to replace existing systems with something similar, rather than exploring alternatives.

Supply chains

According to industry experts, heat pumps for heating in commercial buildings are commercially available, however low demand means it is often not possible to access a heat pump option quickly when existing equipment fails.

Large commercial heat pumps for both space heating and space cooling are imported, although a small number of firms design and build components in Australia.

Supply chains for heat pumps for both space heating and water heating will need to be developed as installation of these systems scales up so that systems are available for purchase. As this occurs, an opportunity exists for greater domestic involvement in the supply chain to provide equipment that is tailored to Australian conditions.

BOX 24: Ground source heat pumps in public buildings in China

In China, GSHPs are installed widely in public buildings with central heating demand. The Chinese commercial heat pump market began developing in the 1980s, specifically with GSHPs, driven by ambition to reduce emissions and pollution associated with the burning of fossil fuels.[151] Low technical expertise and limited experience within the market caused the market to lag in the early 2000s, with just 80 manufacturers in the country. By 2012, the number of manufacturers expanded to 4,000 and the market is now in mature stages of development.

The development of the heat pump market in China, while slow to develop, can be used as a guide by Australia in developing its own commercial heat pump market.

151 Yang, L. 2020, *Heat pump market development in China*, IEA HPT Magazine 39, p. 14-17.

6.3.2 Financial barriers

The business case for heat pump deployment in commercial buildings is difficult to generalise. The economics vary based on a range of factors, including:

- Local prices of different fuels – particularly natural gas and electricity;
- Capital cost, including equipment, installation, electrical upgrade and necessary building costs;
- Overall operational costs, including ongoing maintenance and supervision;
- Availability and cost of in-situ renewable energy generation; and
- Organisation specific factors, such as cost of finance and discount rates.

Buildings that are designed for the initial installation or later retrofit of all-electric systems will face lower costs overall, as requirements of heat pump systems can be considered in initial building design and construction.

Where heat pumps are suitable as drop-in replacement technology – such as replacing an existing hot water system with a heat pump system, or replacement of a standalone heating system with a split-system reverse cycle air conditioner – building a business case may be straightforward. Where more complex installation and integration is required – such as for retrofits in large commercial buildings – the economic case becomes more complex and non-economic factors may have a greater influence on the business case.

Relevant non-economic factors could include delivering on emissions reduction pledges, opportunity cost and sensitivity to disruption associated with building and installation works in retrofits, and stakeholder perception and expectations of different technologies.

Consultation undertaken for this report suggests that air-source heat pump systems typically had an upfront cost 3 – 4.5 times higher than an equivalent gas boiler system. Where lifetime costs are considered, operational cost savings may provide heat pumps with an advantage. As the heat pump market strengthens, economies of scale will likely drive down costs, making heat pumps more attractive in a wider range of applications.

6.4 Actions to accelerate deployment in commercial buildings

For Australia to unlock the potential energy and emissions savings in commercial building heat pump technology, governments and industry can work together to:

- Develop and implement **standards** for heat pumps;
- Conduct **pilot deployments** to gain and share data and experience;
- Expand the **skills** of those involved with heat pumps;
- Engage with global **supply chains** to ensure availability;
- Highlight operational and lifetime **costs** to improve business cases; and
- Explore **integration** and **innovation** to fully capture heat pump benefits.

This paper identified near term opportunities to accelerate heat pump deployment in five of seven categories (bolded below):

1. **Strategy**;
2. Research and development (R&D);
3. **Experience and early deployment**, including pilot projects;
4. **Regulation and standards**;
5. **Integration** with renewable energy sources;
6. **Awareness**, including guides, training and campaigns; and
7. Deployment at scale, including enabling incentives.

6.4.1 Priority recommendation: Commercial building retrofit demonstration program

Although in some instances, commercial buildings have a well-developed framework that incentivises good energy and emissions efficiency, market maturity for commercial building heat pumps – especially for retrofits – appears to be low. Interviewees indicated that while heat pump technology for commercial buildings has a relatively high degree of technological readiness, lack of market knowledge and expertise is a major barrier, particularly for large scale retrofits.

Extensive piloting and early deployment of heat pump systems in large buildings could gather valuable data and lessons about heat pump retrofits. This could spread knowledge and expertise amongst engineering professions, as well as assist commercial building owners in developing effective business cases for heat pump installation. Existing knowledge-sharing mechanisms, such as ARENA, can play a significant role in accelerating awareness of the applicability of technology. Industry and professional associations can also be expected to play a role in developing awareness amongst building design professionals, who will ultimately advise clients on appropriate thermal services for their building and requirements.

A program to fund retrofits for a limited number of commercial buildings – as a pilot and demonstration program – would bring expertise, awareness and knowledge about heat pumps to the commercial buildings sector. Efforts to develop skills and expertise amongst building professionals in higher-grade building tiers, as well as the development of supply chains, would have important flow-on effects that would create economies of scale and reduce barriers to deployment in lower-grade commercial buildings.

Large commercial buildings with centralised plantrooms are an important target for retrofit projects, as they have increased complexity in changing to heat pumps. Consideration could also be given to including a limited number of new buildings in the program, to demonstrate all-electric building techniques in different types of commercial buildings.

Sector-scale facilitation could also accelerate opportunities to gain experience from early deployment. For example, proactive engagement between government, industry and commercial building owners could identify buildings that will require system replacements in the coming two to five years and work with building owners and managers to begin designing heat pump systems for these buildings now.

To encourage retrofits of large buildings, an opportunity exists to rapidly conduct in depth feasibility studies and pilots which build experience and confidence in heat pumps for space heating. The ARENA model – including a strong emphasis on capability building and knowledge sharing – would accelerate the learning curve around this technology. This would help build a pool of skilled professionals to scale up deployment in the medium term, and also provide knowledge and data for Australian supply chain participants to identify opportunities for future involvement and innovation in heat pump deployment.

Action

	Activity	Actor
C1	**Fund a major new ARENA program to pilot and demonstrate heat pump retrofit projects in larger commercial buildings.** Horizon: 1-5 years Areas: Experience and early deployment; Awarenes	Commonwealth

Development of a commercial building transformation initiative from ARENA would support rapid gathering of data and experience in early deployment, enabling heat pump services and applications in large commercial buildings to progress along the diffusion curve with results disseminated through outreach programs to building owners, designers, installers and facility managers.

6.4.2 Supporting recommendations

Building codes

Building codes are as important in commercial buildings as they are in residential buildings at shaping the energy and emissions associated with a building. Both the *Report for achieving low energy existing commercial buildings in Australia* and the *Report for achieving low energy commercial buildings in Australia* acknowledge the need for low energy commercial buildings to reduce carbon emissions, provide low energy bills, save energy, and improve resilience to climate change impacts.[152, 153]

Scaling up heat pump installations for the relevant applications in existing commercial buildings, and encouraging their installation as the default in new commercial buildings, can help achieve the objectives of the *Trajectory* for commercial buildings. Building codes should be aligned with the *Trajectory*, and encourage the development of zero carbon and energy-ready buildings, rather than buildings that need to be retrofitted in the future.

While technology neutrality remains an important principle of government policy, incorporating ambitious performance standards into strategic policy can encourage the installation of currently available technology to deliver thermal services affordably and support national emissions reduction commitments.

152 Council of Australian Governments (COAG) Energy Council, 2019, *Report for achieving low energy existing commercial buildings in Australia*, Commonwealth of Australia, Canberra, p. 24-26.

153 Council of Australian Governments (COAG) Energy Council, 2018, *Report for achieving low energy commercial buildings in Australia*, Commonwealth of Australia, Canberra.

Action

	Activity	Actor
C2	**Align building codes and strategy with a trajectory for net zero-ready buildings, including:** **1. Continuing to advance the NCC and the *Trajectory for low energy buildings* and aligning the NCC to the *Trajectory*; and** **2. Ensure the NCC and NABERS encourage installation of more efficient appliances like heat pumps.** Horizon: 1-3 years Areas: Strategy; Regulation and standards	Commonwealth States and territories

The *Trajectory* sets a comprehensive roadmap for collaboration between state and federal governments to improve the energy performance of new and existing commercial buildings over time. All stakeholders should continue to work together to ensure the *Trajectory* drives the adoption of more efficient, lower emissions technologies, including heat pumps.

The NCC shapes the types of appliances that are installed in new commercial buildings. Plans for increasing the stringency of the NCC in 2025 should specifically address the opportunity to ensure new commercial buildings are zero carbon and energy ready, with provision for anticipated technology needs (such as heat pumps).

Standards

Technical standards covering the design, installation, performance, and maintenance of commercial heat pumps are currently under-developed. Standards relating to the performance assessment of solar and heat pump water heaters up to 65kW include AS/NZS 4234 and AS/NZS 5125), however these standards are not specific to commercial settings.

The GEMS Act sets MEPS for commercial chillers, however compliance has proven to be difficult due to the bespoke nature of the technology.[154] MEPS for commercial air conditioners larger than 65kW come into force from October 2022.[155] In-situ testing should be conducted to ensure that actual performance aligns with the standards.

The Australian commercial property sector would benefit from standards that ensure high performance heat pumps are the preferred choice in the market. Given the global nature of the heat pump industry, it will be important for Australia to adopt global best practice standards and encourage the development of innovative solutions. Specifically, aligning Australian standards with those of a larger market – for example, the EU or California – would provide the opportunity for Australian manufacturers to plug directly into these markets and reap the benefits of well-established supply chains.

154 Equipment Energy Efficiency (E3) 2018, *Update: Proposed changes to regulation of liquid chilling packages*, Commonwealth of Australia, Canberra.

155 Australian Government 2020, *Greenhouse and Energy Minimum Standards (Air Conditioners above 65kW) Determination 2020*, Australian Government, Canberra.

Action

	Activity	Actor
C3	**Consider harmonising Australian standards for commercial heat pumps with international standards.** Horizon: 1-3 years Areas: Regulation and standards	Commonwealth

BOX 25: Standards in Japan

In Japan, nearly all new commercial buildings are built with heat pumps for heating and cooling. This is due partly to product testing against standards.

The Japan Air Conditioning and Testing Laboratory (JATL) is supported by the Japan Refrigeration and Air Conditioning Industry Association to randomly test the actual energy efficiency level of one product each year to ensure it aligns with its specified energy efficiency level.[156] The random nature of product selection ensures all products meet the target level.

Leveraging NABERS and CBD

The National Australian Built Environment Rating System (NABERS) is an important driver of energy efficiency in commercial buildings. *NABERS Energy* provides information about a building's energy performance compared to equivalent commercial buildings. The Australian Government's Commercial Building Disclosure (CBD) program requires mandatory disclosure of NABERS ratings for offices above 1000 square metres, before sale, lease or sublease. Together, these initiatives overcome a key market failure in relation to commercial buildings – information asymmetry – in the commercial building market.

Renewable energy penetration in the electricity grid is increasing, which is driving a decrease in the emissions associated with grid supplied electricity. In recognition of this, in 2020 NABERS announced it will begin updating the emissions factors used in NABERS Energy ratings. This means that as the grid decarbonises, ratings of electric buildings will improve relative to those that continue to rely on gas. NABERS is also adding a Renewable Energy Indicator (REI) to sit alongside the traditional star rating, which will display the percentage of a building's energy that is sourced from renewable sources.

Both these developments could have a significant impact on demand for all-electric buildings over time.[157]

Expansion of the CBD scheme to include new building types beyond office buildings would further improve the visibility of energy efficiency through the disclosure of NABERS Energy ratings.

In addition, requiring disclosure of the forthcoming NABERS REI could help encourage adoption of equipment that can pair with renewable energy. NABERS can also help validate the assumptions around savings resulting from heat pumps, with actual performance levels being reflected through NABERS Energy ratings.

156 The Japan Refrigeration and Air Conditioning Industry Association (JRAIA) 2021, *About JATL*, JATL, Kanagawa, Japan.

157 National Building Energy Rating Scheme (NABERS) 2022, *NABERS to release a renewable energy indicator*, NSW Government, Sydney.

Action

	Activity	Actor
C4	**Harness the successful NABERS and CBD programs to power a transition to heat pumps in commercial buildings, by:** **1. Expanding the CBD program to new commercial building types, and requiring disclosure of the NABERS Renewable Energy Indicator; and** **2. Engage with commercial building owners through these programs to build awareness of heat pump technology.** Horizon: 1-3 years Areas: Regulation and standards; Awareness	Commonwealth

Expanding the building types covered by the CBD program requirement for mandatory disclosure of NABERS Energy ratings and including the proposed Renewable Energy Indicator would encourage the reduction of energy consumption in more types of commercial building and encourage electrification of commercial building space and water heating systems through heat pump installation that will improve NABERS Energy ratings.

Similarly, driving engagement with building owners and operators through these well-known programs provides a platform to build awareness of new technologies that can improve performance, like heat pumps.

Unlock demand flexibility through heat pumps in commercial buildings

Like residential buildings, commercial buildings can take advantage of demand flexibility by shifting heating and cooling processes to periods of high availability of renewable electricity and away from periods of stress on electricity supply infrastructure.[158]

Because they are larger, commercial buildings have additional opportunities to take advantage of thermal inertia or thermal storage. For example, thermal batteries can utilise substances such as water to store thermal energy, for example by melting stored ice with waste heat and removing the stored heat by re-freezing the water when the building needs to be heated.[159] Thermal storage options include hot or chilled water, phase change materials, the ground, an aquifer or the building thermal mass itself. Hot water systems including heat pumps have been used as a controlled load in a number of demand management programs. Sophisticated heat pump design is needed to unlock these benefits. Lessons from international examples and a small number of local examples can be drawn and adapted to the Australian context so market experience can be built to deliver innovative solutions to unique building conditions.

Action

	Activity	Actor
C5	**Establish a targeted ARENA program that supports commercial building owners to pilot demand management projects and share learnings.** Horizon: 1-3 years Areas: Strategy; R&D; Experience and early deployment; Integration with renewable energy sources	Commonwealth

A targeted program to support commercial building owners to rapidly gain experience and share learnings around demand management could ensure electrification efforts are accompanied by sophisticated energy management practices.

ACTION

158 Brinsmead, T., et al 2020, *Flexible Demand B4: Opportunity Assessment Final Report*, RACE for 2030, Canberra.

159 Nadel, S. and Perry, C. 2020, *Electrifying space heating in existing commercial buildings: opportunities and challenges*, American Council for an Efficiency Economy (ACEEE), Washington, DC, p. 53.

7

The opportunity in industrial processes

Summary

- Heat pump deployment in industrial processes could save from **1874 to 8337 PJ and 80 to 391 Mt CO_2e** by 2050 in the modelled scenarios.
- **Immediate opportunities exist** to deploy heat pumps in low-temperature heating and cooling operations across a wide range of industrial applications.
- In the future, heat pump technology could also substantially **reduce emissions from alumina processing**.
- Key actions to accelerate deployment of heat pumps in industry include:
  - Development of a **national process heat initiative**, including policy development, piloting and demonstration, and ongoing R&D; and
  - Supporting a wide **rollout of metering and energy management systems** to build the business case for investment in heat pumps.

7.1 Sector overview

Of the sectors examined in this report, industrial processes – especially manufacturing and food processing – present the greatest opportunity for energy and emissions savings through the adoption of heat pumps. Activities classed as manufacturing are responsible for 20% of Australia's total final energy consumption, which in 2018-19 was 861 PJ and accounted for about 26% of the country's total emissions.[160] Energy and emissions savings from deployment of heat pump technology in the industrial sector comprises more than half of the potential abatement modelled in the *Heat Pump Energy and Emissions Savings Model*.

However, the nature of the industrial sector means that a lower level of confidence can be associated with these estimates, as the deployment of heat pumps in industrial applications is subject to a greater range of uncertainties and barriers than those in residential settings or commercial buildings.

Table 16 shows that rapid deployment of heat pumps could result in very substantial emissions savings – and even more when coupled with a rapid transition to low-emissions electricity under the AEMO 'Step change' scenario. This is principally due to fuel shifting from gas to electricity.

In this chapter, an additional scenario is modelled – industrial slow growth – to explore the effects of lower industrial growth and lower efficiency gains in the industrial sector, while maintaining a relatively linear uptake trajectory. This reflects the reality that investments in upgrading industrial equipment and processes require coalescence of large amounts of capital, skills and technology, which may not occur as quickly as in other sectors of the economy, and that minimal growth has occurred in the manufacturing sector over the past decade.[161]

160 Department of Industry, Science, Energy and Resources (DISER) 2020, *Australian Energy Update September 2020* – Australian Energy Statistics, Commonwealth of Australia, Canberra, p. 17.

161 Australian Bureau of Statistics 2022, *Australian industry by division*, cat no. 8155.0, Table 1, Australian Government, Canberra.

Heat pump penetration scenario	Cumulative energy savings to 2050 (PJ)	Cumulative greenhouse gas emission savings to 2050 compared to baseline ($MtCO_2e$) AEMO 'Central'	AEMO 'Step change'
Late adoption, 100% deployment 2040-2050	1874	80	90
Linear to net zero 2050 (3.3% p.a.)	5124	209	243
Linear to net zero 2050 + extra efficiency (+2 + 2%)	6473	311	320
Supercharged deployment to 100% in 10 years (10% p.a.)	8337	332	391
Slow industrial growth	3171	129	149

Table 16 Industrial sector results from the *Heat Pump Energy and Emissions Savings Model*

Cumulative abatement and energy reductions are shown in **Figure 23** and **Figure 24**. It is clear that the most important factor in maximising abatement from heat pumps in the industrial sector is early deployment. Early deployment has a marked impact on the size of the cumulative emissions associated with industrial processes, supporting a lower emissions budget to 2050.

The size of this opportunity is due to the unique characteristics of heat pumps, their ability to be deeply integrated into manufacturing processes, and the opportunity to deliver multiple services with a single technology. In some cases, heat pumps can provide both cooling and heating simultaneously, improving overall efficiency by providing two services without using more energy. Utilising waste heat from onsite processes can dramatically improve heat pump efficiency, an opportunity that is readily available in many settings in this sector. Additionally, manufacturing sites are often well placed to accommodate thermal storage.

Cumulative energy reduction – industrial sector

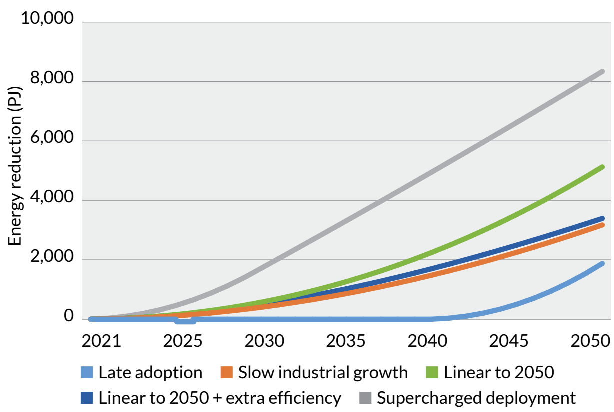


Figure 23 Modelled cumulative energy reductions in the industrial sector across heat pump deployment scenarios

Cumulative emissions reduction – Step change

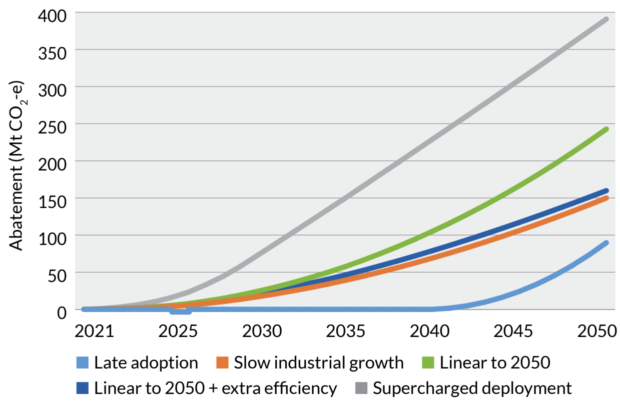


Figure 24 Modelled cumulative emissions reductions in the industrial sector across heat pump deployment scenarios

Although the opportunity is very large, unlocking it will require a major national effort. Use of heat pumps for process heating in industrial processes is very low – see **Figure 25**; less than ten sites in Australia currently utilise the technology for process heating. [162]

162 Jutsen, J., Pears, A. and Hutton, L. 2017, High temperature heat pumps for the Australian food industry: Opportunities assessment, Australian Alliance for Energy Productivity, Sydney.

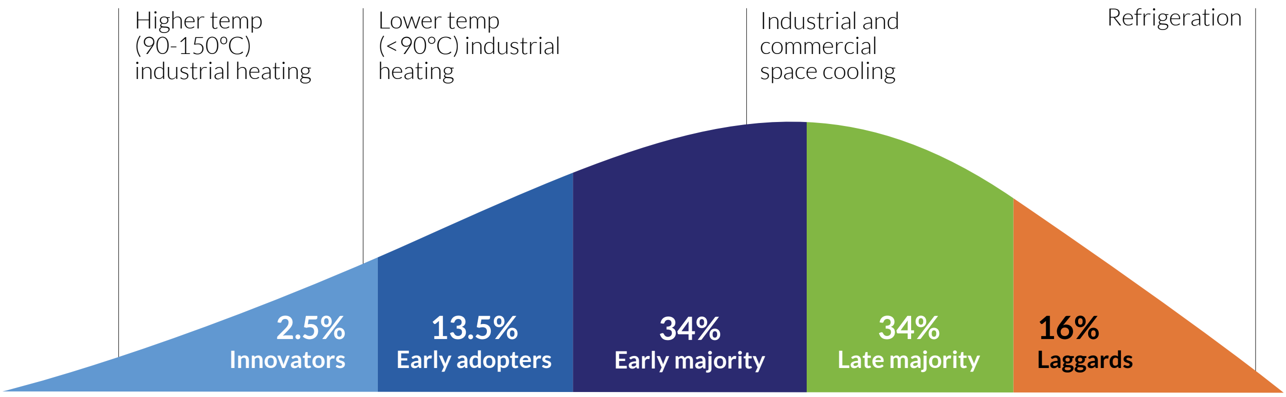


Figure 25 Estimated adoption level for heat pump technologies in industrial processes

Australia is not unusual in this regard; while interest in heat pumps in industry is high around the world, adoption rates are low in most nations. Some nations are investing to unlock the opportunity, and Europe is leading the way, making major investments to drive heat pump adoption in industrial processes.[163] Australia can join this global effort to unlock potential of this technology both in Australia and around the world.

A priority recommendation for driving the adoption of heat pumps in the industrial sector is shown in **Table 17**:

	Activity	Actor
I1	**Develop and implement a national process heat initiative, including:** **1. Strategy and timeline for decarbonising process heat;** **2. A map and database of industrial fossil fuel boilers and burners, and model of electrical impacts of heat pump conversion;** **3. A new program to pilot heat pump demonstration projects in manufacturers and food processors; and** **4. A program of R&D for high-temperature heat pump applications and MVR technologies.** Horizon: 5-10 years (initial phases); 10+ years (R&D) Areas: Strategy; R&D; Experience and early deployment; Awareness; Deployment at scale	Commonwealth

Table 17 Priority recommendation for driving the adoption of heat pumps in the industrial sector

163 European Commission 2017, *Horizon 2020 work programme: Secure, clean and efficient energy*, European Commission, Brussels.

7.2 Heat pump applications and opportunities in the industrial sector

7.2.1 Australian opportunities

Heat pumps already provide thermal energy services in the Australian industrial sector – most commonly for space cooling and refrigeration. However, there is significant potential to expand their application to supply process heating loads.

Electrification of manufacturing is the critical first step in the decarbonisation of industry. Initial electrification involves deployment of heat pumps and mechanical vapour recompression (MVR), progressing to deployment of steam generators, microwave, infrared and radio frequency heating.[164,165,166]

The modelling from this report indicates that there are three significant energy and emissions reduction opportunities arising from the application of new heat pumps in manufacturing:

- Process water and product heating;
- Process air heating; and
- Mechanical vapour recompression (MVR) in alumina.

Mechanical vapour recompression (MVR) technology is a variant on conventional heat pumps and is fully developed with sufficient capacities for distillation and evaporation processes in the chemical, dairy, wastewater, desalination and pulp and paper industries. MVR can also be used for cooking and digestion processes. The application of MVR within alumina processing has the potential to significantly reduce emissions and operating costs.

Common process heating applications with great potential to switch to heat pumps include:

- **Drying** products such as timber (40-100°C), air for milk powder (preheating to >80°C) and potatoes (70°C), malt (35-80°C), painted parts (up to 120°C) and French fries (70°C);
- **Washing, cleaning, and sterilising** within the food industry (65-90°C) and metal or plastic parts (60°C);
- **Process water**, including brewing (85°C) and boiler feedwater (90°C);
- **Pasteurisation**, including milk, butter and cheese (73°C);
- **Concentrating**, including wort boiling, milk and sugar solutions (75-100°C); and
- **Space heating**, including circulated hot water (50°C) and district heating (70-90°C).[167]

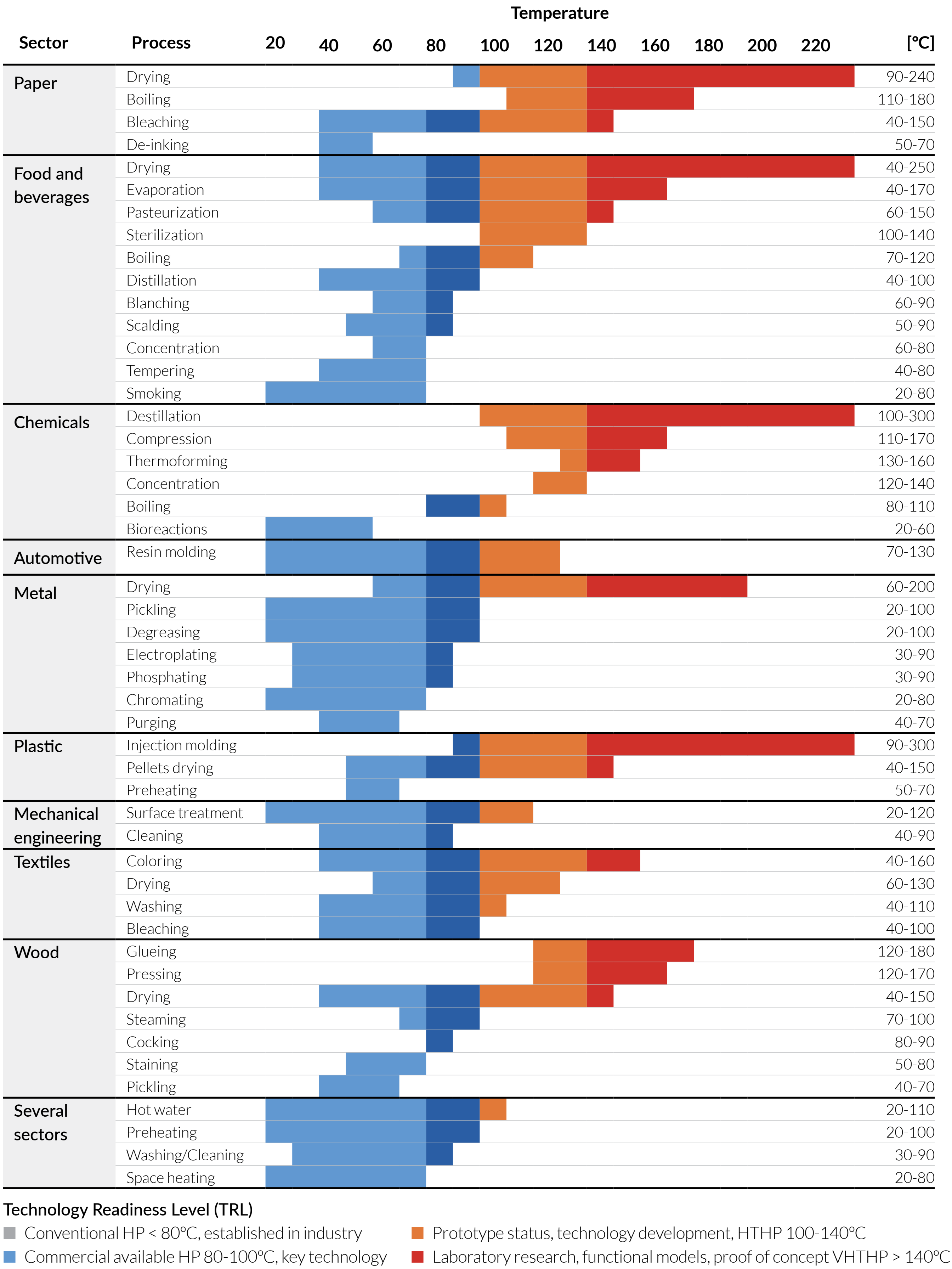
Further examples are shown in **Figure 26**.

164 Madeddu et al. 2020, *The CO_2 reduction potential for the European industry via direct electrification of heat supply (power-to-heat)*, Environmental Research Letters 15(12), 1-14.

165 Energy Efficiency Council (EEC) 2020, *Navigating a dynamic energy landscape: a briefing for manufacturers*, EEC, Melbourne, p. 18.

166 Beyond Zero Emissions (BZE) 2018, *Zero carbon industry plan: Electrifying industry*, BZE, Melbourne, p. 5-6.

167 Arpagaus, C. 2020, *A2EP briefing: Advances in industrial heat pumps – Supplier update, suitable refrigerants and application examples in food & steam generation*, Australian Alliance for Energy Productivity, Sydney.



Source: Arpagaus 2020.

Figure 26 Applications for heat pump technology in industrial processes.

Different industrial sectors use different combinations of these operations. An overview of applications by subsector is provided in **Figure 27**:

Subsector	Applications				
MINERALS	Chemical processing	Washing	Melting		
FOOD & BEVERAGE	Dewatering	Cooking	Pasteurisation	Washing	Preserving
PULP & PAPER	Drying	Washing	Bleaching		
WOOD PRODUCTS	Drying	Humidification	Heating		
METAL FORMING	Pre-heating	Melting	Heat treatment	Forming	
PRINTING	Drying	Curing			
TEXTILES & LEATHER	Washing	Bleaching	Dyeing		

Figure 27 Process heating applications by subsector

Source: Australian Alliance for Energy Productivity (A2EP) 2020.

7.2.2 Global trends

Heat pumps designed for use in manufacturing and food processing are increasingly available overseas.

Industrial heat pump systems for heating up to 95°C are readily available, and systems that can heat up to 110°C are becoming more common. The maximum heat output from industrial heat pumps achieved to date is 165°C in some Japanese systems,[168] and 160°C in Europe[169] in demonstration projects. Globally, heating capacities of individual industrial heat pumps reach up to 20 megawatt (thermal), although increasingly larger heat pumps are being developed.

Europe is the global leader in heat pump adoption in industry. Government programs have supported the development of supply chains and the deployment of heat pumps across the continent, for applications including:

- Food processing, including meat processing, chocolate, cheese, vinegar and margarine;
- Beverage, including dairy, breweries, malt and distilleries;
- Chemical processing, including abrasives, plastic, coatings, printing and dyeing;
- Machinery, including chipboard, plastic, and metals; and
- Agriculture, including flowers and tomatoes.

168 Jutsen, J., Pears, A. and Hutton, L. 2017, *High temperature heat pumps for the Australian food industry: Opportunities assessment*, Australian Alliance for Energy Productivity, Sydney, p. 9.

169 Ibid, p. 58.

Many of these sites have heat pumps operating with a COP greater than 4, and have achieved overall site energy and carbon savings in excess of 30%.[170]

BOX 26: Industrial heat pumps in the United States

Use of heat pumps for industrial applications in the United States has been low, due largely to cheap gas prices giving an advantage to gas-fired equipment.

However, interest is growing in the role of heat pumps in the decarbonisation of industrial processes.

The *Renewable Thermal Collaborative* was recently awarded a $10 million USD grant for a major effort to scale up use of 'renewable thermal energy', including electrifying industrial heating via heat pumps.

7.2.3 Technology to watch: mechanical vapour recompression

Mechanical vapour recompression (MVR) is a heat pump variant traditionally employed for low-temperature evaporation processes which need only a small – less than 15°C – temperature lift and typically deliver COPs greater than 10. The technology is most commonly used below 100°C but can deliver heat up to 250°C. Multiple stages can achieve high efficiency with larger temperature increments.[171] Consultation has found that MVR technology has been employed for processes such as milk evaporation prior to drying, black liquor evaporation in the wood pulping process, and wastewater evaporation plants concentrating the water produced by coal seam methane wells in Queensland.

The technology readiness level (TRL) of MVR varies widely according to application. TRL is a qualitative assessment of the maturity of the underlying technology of an innovation, and is distinct from commercial readiness that considers market factors – see **Figure 28**.

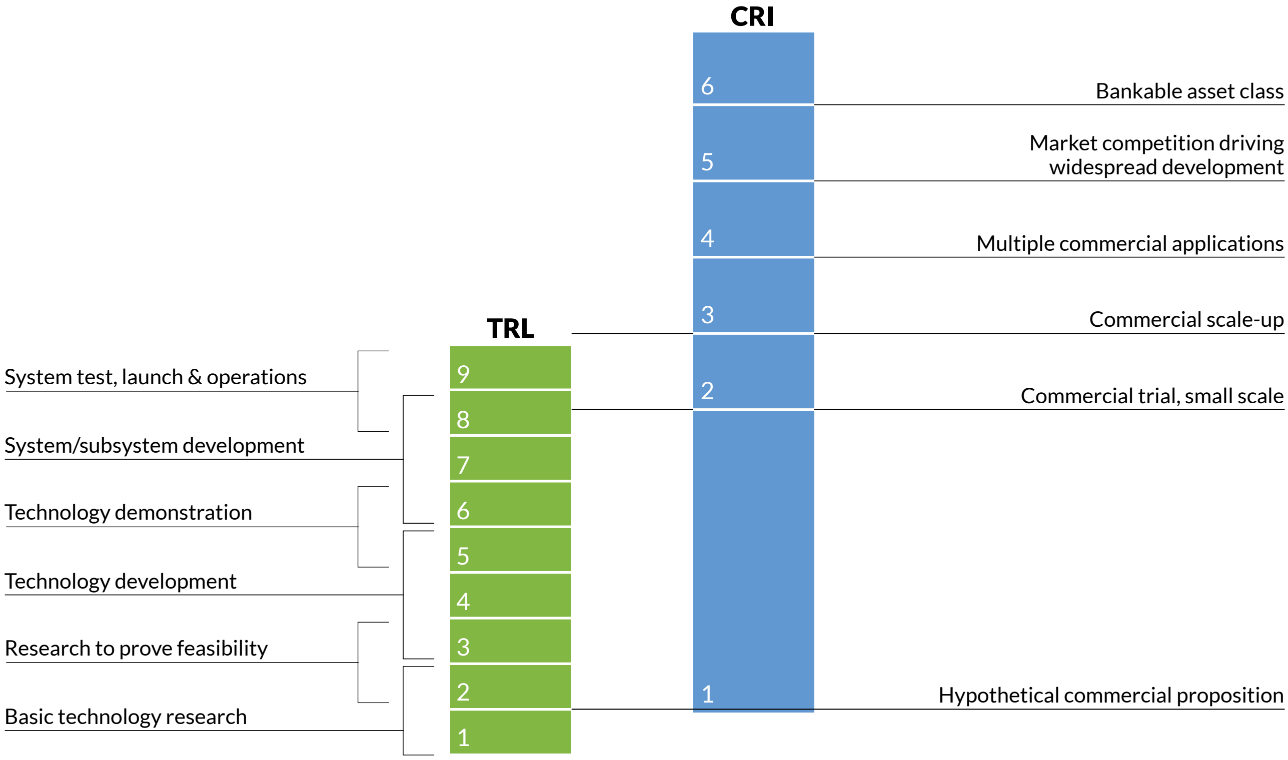


Figure 28 Schematic of technology readiness level (TRL) and commercial readiness indicator (CRI)

170 de Boer, R., Marina, A., Zuhlsdorf, B., Arpagaus, C., Bantle, M., Wilk, V., Elmegaard, B., Corberan, J., and Benson, J. 2020, *Strengthening industrial heat pump innovation: Decarbonizing industrial heat*, Technical University of Denmark, Lyngby, Denmark.

171 Energy Efficiency and Conservation Authority (EECA) 2019, *MVR (mechanical vapour recompression) systems for evaporation, distillation and drying*, New Zealand Government, Wellington.

However, there is significant potential for MVR technology in Australia to be expanded:

- MVR could be applied to a wide range of evaporation processes in manufacturing industries such as sugar refining, fruit juice concentration, chlor-alkali, meat rendering, malt extract, glucose, fructose, starch and ethanol distillation. Application of MVR technology in each of these industries has an estimated technology readiness level (TRL) greater than five;
- MVR technology could be utilised in the digestion and evaporation stages of alumina processing. MVR technology used for evaporation processes is well developed and proven in many applications and therefore it is estimated to have a TRL greater than seven. MVR technology at the higher temperatures required for alumina digestion – approximately 150-160°C for west coast refineries and 230-250°C for refineries on the east coast – has not yet been applied at scale but is considered feasible by some technology suppliers. The TRL for MVRs on alumina digestion is assessed to be four; and
- Although not yet proven, MVR could be used in industries such as meat rendering, vegetable cooking, snack foods, prepared foods, condiments and sauces. The current TRL for using MVRs in cooking processes is estimated to be four.

MVR in alumina – a key opportunity

In 2020, Australia's six alumina refineries produced 21.4M tonnes of alumina and consumed 221 PJ of energy – 4% of Australia's total final energy consumption. Of that, approximately 150 PJ was used for heating, resulting in approximately 15M tonnes of CO_2e per annum.[172] Australia produces approximately 100M tonnes of 'hard to abate emissions' from direct combustion per annum; these six sites are responsible for 15% of these emissions.[173]

The *Heat Pump Energy and Emissions Savings Model* finds that MVR technologies could lead to abatement of 10 Mt CO_2e per annum. Industry experts estimate that the transition cost is between $2-5 billion and would significantly lower the operating costs of Australia's alumina refineries.

In January 2021, ARENA provided a grant for Alcoa of Australia Ltd to undertake a feasibility study to replace fossil fuel steam generation with an MVR module at their Western Australia alumina refinery. If the feasibility study is successful, the grant will see an existing evaporation plant retrofitted with MVR technology and is expected to be operational in 2023. The grant also includes a study to determine the cost and emissions reduction potential for all Australian refineries when converting evaporation and digestion processes to MVR technology.[174]

172 Evans, M. et al 2021, *B3 opportunity assessment: Electrification & renewables to displace fossil fuel process heating – report at a glance*, RACE for 2030, Canberra.

173 Australian Aluminium Council n.d., *Sustainability*, Australian Aluminium Council, Canberra.

174 Australian Renewable Energy Agency (ARENA) 2021, *Mechanical vapour recompression for low carbon alumina refining*, Australian Government, Canberra.

BOX 27: The role of heat pumps in the agriculture sector

This section considers use of heat pump technology in the food supply chain at the processing stage. However, opportunities also exist to use heat pumps at the site of primary production. In many cases, these sites lack access to reticulated natural gas, or even mains electricity. This means that heating requirements are often supplied by more emissions-intensive fuel types, such as LPG or diesel fuel.[175]

In aggregate, agriculture is responsible for just 2.3% of final energy consumption in Australia and on-farm energy use accounts for about 9% of agricultural sector emissions.[176] However some sub-sectors are highly energy intensive, and justify an effort to bring the benefits of heat pump technology to farms.

The primary applications of heat pumps in the agriculture sector include:

- Milk chilling;
- Water heating;
- Warming drinking water for animals;
- Space heating and space cooling of on-farm buildings, including farmhouses, greenhouses and poultry sheds;
- Process heating, or drying;
- Refrigeration; and
- Thermal energy for rearing animals.

Quantitative characterisation of these opportunities is out of scope for this report. However, we know that the requirements for different thermal services vary across different farm types and locations – for example, a dairy farm will require significantly more hot water for washing and sanitary processes compared with a broadacre cropping farm.

In those locations without access to mains electricity, electrical services are provided by micro generation such as solar PV, wind turbines, small-scale hydro and generators running on diesel or LPG. Using highly-efficient heat pump technology – particularly when coupled with thermal storage – can reduce the amount of electricity that must be generated from fossil fuels, can reduce the amount of renewable energy capacity required and substantially reduce running costs.

Integration and innovation opportunities also exist on farms.[177] For example, dairy farms could use a heat pump to chill milk and capture the waste heat from refrigeration to heat water for sanitary purposes. For a process that requires high-temperature heat for drying, the resultant lower-grade waste heat could be captured and used to provide warming for animal rearing purposes. These operations could be integrated with on-site renewable energy generation to provide even greater savings in operating costs.

Initiatives to accelerate deployment of heat pump technologies could take advantage of existing mechanisms to disseminate information and expertise to farmers – such as the Rural R&D Corporations and state and territory primary industry departments – and target specific, energy intensive sub sectors.

Across Australia, it is estimated that there are approximately:

- 5,000 dairy farms;[178]
- 2,395 vegetable growing farms;[179]
- 337 commercial egg farms;[180]
- 800-900 commercial chicken meat growers;[181] and
- 2,700 pig production sites.[182]

Across these businesses there is significant potential for heat pumps to replace existing technologies. The relative uniformity across these different types of farms means roll-out of programs to support heat pump adoption could be relatively straightforward, with additional benefits gained from economies of scale. Additionally, some of the barriers which may constrain deployment of heat pumps in other commercial operations – such as space constraints or planning rules – are less likely to apply in rural enterprises.

175 Department of Industry, Science, Energy and Resources (DISER) 2020, *Australian Energy Update 2020* [Table F1 Australian energy consumption, by industry and fuel type, energy units], Commonwealth of Australia, Canberra.

176 Gjerek, M., Morgan, A., Gore-Brown, N. and Womersley, G. 2021, *Diesel use in NSW agriculture and opportunities to support net zero emissions*, Australian Alliance for Energy Productivity, Sydney.

177 RACE for 2030 2021, Electrification & Renewables to Displace Fossil Fuel Process Heating, RACE for 2030, Canberra.

178 Dairy Australia 2021, *Cow and Farms Data*, Dairy Australia, Melbourne.

179 Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), *Australian vegetable growing farms: an economic survey 2017-18 and 2018-19* [Figure 3], Australian Government, Canberra.

180 Australian Eggs 2021, *How many egg farms are there in Australia?*, Australian Eggs, Sydney.

181 Australian Chicken Meat Federation 2021, *Structure of the industry*, Australian Chicken Meat Federation, Sydney.

182 Australian Pork, 2021, *Industry facts*, Australian Pork, Canberra.

7.3 Challenges

The industrial sector shares many of the barriers in deploying heat pumps as other sectors. There are a range of technical challenges to installing heat pumps in industrial applications, and it is probable that heat pump technology will not be technically or economically feasible for use in all industrial sectors – even for the relatively conservative set of opportunities modelled for this chapter. There are a range of constraints that could prevent heat pump installation, such as lack of access to a suitable heat source or sink, or space constraints, or other physical or technical factors. The *Model* is unable to quantify these constraints but equally technological progress may ameliorate some of these constraints, or widen the potential application for heat pump technology.

Although there are a range of technical barriers that may not be able to be overcome, other challenges exist – based on less rigid physical or technical constraints – which may be met. This section examines some additional barriers that industrial processes may face, which could be overcome through action of government or industry.

7.3.1 Information and knowledge barriers

Data and information

Very few manufacturers and food processors have well mapped needs for heating demands and temperatures for different on-site processes.[183] Better metering of mass flows and temperatures would allow for preparation of mass and energy balances, energy flow diagrams and proper modelling of energy demands. These are important for optimising the size of heat pumps and thermal batteries.

Improved granularity in metering could pave the way for the adoption of energy management systems (EnMS) for manufacturers to better understand and manage on-site energy consumption.

Aligning heat supply temperature with demand temperature

Most manufacturers and food processors only need low-grade heat below 160°C. However, industry consultation suggests that on many sites, heat for low temperature processes is delivered at higher temperatures than required.

The discrepancy between supply temperature and demand temperature is often the result of decisions made at the time of initial system design, and can cause confusion when assessing the viability of a heat pump replacement. For example, steam generated in a boiler at a dairy factory will typically be delivered at 160-170°C, however the majority of the heat demand is for cleaning, sterilising and pasteurising, all below 85°C.

Wide-scale adoption of heat pumps will require more focus on aligning heat supply temperatures with actual demand temperatures. Heat pump efficiency falls as temperature rise increases, and the marginal capital cost of additional heat pump capacity is much higher than for gas boilers.

Smart process design also opens up other opportunities for broader efficiency gains. Low temperature waste heat flows can also be efficiently upgraded to higher temperature heat using a heat pump and used in other processes.[184]

Heat pumps can also be effectively used in applications that require heat at a higher temperature than current, commercially available heat pumps alone can deliver. For example, more than 80% of the energy required to create 160-180°C steam is required to boil the water. Heat pumps can be used to deliver steam at just over boiling point – e.g., 120°C – and other technologies can be used to 'top up' the heating process.

Heat pumps could also supply a portion of the heating demand above 250°C, for example by preheating air before going into a high temperature calcining or drying process.

183 Australian Alliance for Energy Productivity (A2EP) 2020, *Renewable energy for process heat opportunity study: Project report*, Australian Renewable Energy Agency, Canberra.

184 Beyond Zero Emissions (BZE) 2018, *Zero Carbon Industry Plan: Electrifying Industry*, BZE, Melbourne.

7.3.2 Economy-wide barriers

Supply chains

Suppliers of heat pumps for heating in industrial processes exist in Australia, however, uptake is currently low.

Off-the-shelf heat pumps are generally not suitable for industrial applications, and may struggle in a demanding manufacturing environment. Larger industrial heat pumps are typically provided as a custom, bespoke solution built to meet specified needs from the end user.[185] This is the main pathway to market for the industrial refrigeration companies likely to supply heat pumps, who are located in most capital cities in Australia.

Major equipment suppliers that provide compressors, heat exchangers and other componentry are also present in Australia, with local parts and service capability. However, Australia lacks local representation of some of the heat pump suppliers that are at the forefront of R&D overseas.[186]

Confidence in the local supply chain and heat pump technology has a high risk of collapsing if lower grade, domestic or commercial heat pumps are employed in the manufacturing market. Pilot programs and market education is needed to help the industrial sector determine the specifications for heat pumps to suit their needs.

Skills and expertise

The engineering knowledge to perform design, installation and maintenance work for heat pump packages is present across Australia through a network of industrial refrigeration contractors. However, only a fraction of the workforce possesses sufficient understanding of both heat pumps and manufacturing processes to properly advise end users on integrated heat pump solutions.[187]

The main knowledge gap in the industrial sector is how to integrate heat pumps into industrial processes to maximise performance. A poorly integrated heat pump solution without proper thermal storage and utilisation of waste heat will often be uneconomical.

These gaps could be overcome through a program of pilot projects paired with knowledge-sharing and training. Notably:

- Design costs will reduce as the market gains experience, especially where it is paired with training programs for engineers and installers;
- Low levels of awareness of technical possibilities and economically feasible applications amongst users, consultants, investors, plant designers, producers and installers can be overcome with the knowledge sharing; and
- A focus on reducing the overall capital costs and peak electrical loads of heat pumps with thermal batteries will be important. Partnerships with providers of demand response services should be a component of pilot projects to build experience with suitable pricing and technology solutions.

7.3.3 Financial barriers

Consultation has indicated that upfront costs for industrial heat pumps can be five to ten times higher than those associated with a traditional steam boiler solution. This can be offset through lower ongoing operating costs. The development of a robust business case may make investment in heat pumps a compelling decision, although the overall economics will vary from site to site.

The low market penetration of heat pumps means that there is high potential for improvement through increasing economies of scale.[188] Building the cohort of skilled professionals will lead to more efficient, lower-cost installations. As the skills of these trades and those designing systems improve, knowledge around appropriate sizing and optimisation of systems will grow, driving costs down.

185 Australian Alliance for Energy Productivity, forthcoming.

186 Jutsen, J., Pears, A. and Hutton, L. 2017, *High temperature heat pumps for the Australian food industry: Opportunities assessment*, Australian Alliance for Energy Productivity, Sydney.

187 Australian Alliance for Energy Productivity (A2EP) 2020, *Renewable energy for process heat opportunity study: Project report*, Australian Renewable Energy Agency, Canberra.

188 Australian Alliance for Energy Productivity (A2EP) 202 0, *Renewable energy for process heat opportunity study: Project report*, Australian Renewable Energy Agency, Canberra, p. 9-10.

7.4 Actions to accelerate heat pump deployment in industry

Opportunities to accelerate heat pump deployment exist in five of the seven categories (bolded below):

- **Strategy;**
- **Research and development (R&D);**
- **Experience and early deployment, including pilot projects;**
- Regulation and standards;
- **Integration with renewable energy sources;**
- Awareness, including guides, training and campaigns; and
- **Deployment at scale, including enabling incentives.**

The following actions from government and businesses could accelerate the deployment of heat pumps for industry.

7.4.1 Priority recommendation – Develop a national process heat initiative

As part of a broader national industrial decarbonisation strategy, a process heat initiative could drive emissions reductions and energy savings from industrial process heating. Opportunities exist to deploy heat pumps into low-temperature applications in the near term, with medium term development likely to allow for application into temperatures up to 150°C.

A comprehensive process heat initiative would include a range of strategy, enabling, R&D and deployment elements.

Action

	Activity	Actor
I1	**Develop and implement a national process heat initiative, including:** **1. Strategy and timeline for decarbonising process heat;** **2. A map and database of industrial fossil fuel boilers and burners, and model of electrical impacts of heat pump conversion;** **3. A new program to pilot heat pump demonstration projects in manufacturers and food processors; and** **4. A program of R&D for high-temperature heat pump applications and MVR technologies.** Horizon: 5-10 years (initial phases); 10+ years (R&D) Areas: Strategy; R&D; Experience and early deployment; Awareness; Deployment at scale	Commonwealth

In partnership with industry and key stakeholders (such as state governments), a national process heat decarbonisation initiative will lay the groundwork for deployment of heat pump technology into industry. Enabling work, R&D, demonstration, and knowledge-sharing will be important components of the initiative, which will help build markets and capacity to deploy heat pump technology across a range of industry sectors, as well as effectively integrate heat pumps with renewable energy and demand management. Further information on elements of the initiative is provided below.

Strategy

While the residential and commercial buildings sectors benefit from the framework set out by the *Trajectory for Low Energy Buildings*, no such framework exists for manufacturing or the industrial sector. Development of a framework, drawing on overseas examples such as the UK's *Industrial Decarbonisation Strategy*, could encompass the opportunities identified in this report to accelerate heat pump adoption as just one part of a wider decarbonisation plan for industry.

As Australia's path to achieving net zero emissions by 2050 is further developed by governments, capitalising on abatement opportunities available with existing technology will support early progress towards industrial decarbonisation.

Heat pumps provide a short-term opportunity to reduce energy usage and emissions from process heat delivered at temperatures of up to 90°C, with medium temperature applications (up to 150°C) likely to be available in the medium term. These technologies could form the basis of development of an **industrial process heat decarbonisation strategy**, along with other low-emissions technologies for high temperature applications. Guidance could be drawn from overseas examples, including the development of the New Zealand strategy on reducing emissions from process heat.[189]

Development of a strategy could consider which technologies might complement heat pumps, and timelines for deployment and introduction. A strategy would consider where current and future opportunities for integration with renewable energy exist, as well as potential for flexible demand that could help support grid security.

Build a database of existing industrial heating equipment

A key piece of enabling work is to effectively plan for the implementation of industrial scale heat pumps, and coordinate with energy market stakeholders. Large industrial heat pumps are likely to be significant sources of electrical demand and understanding in advance any constraints that local electricity grids are likely to impose on heat pump deployment is important to success.

Development of a map of potential industrial heat pump deployment would be an important input for AEMO's Integrated System Plan – additional information on likely electrical demand from conversion from natural gas (and other fossil fuel) fired boilers and burners is needed. In New Zealand, the *Regional Heat Demand Database* has recently completed this for regions in the South Island to inform future electrical and biomass needs. This work can also draw on recent work undertaken by the RACE for 2030 CRC under the *Theme B3: Electrification & renewables to displace fossil fuel process heating*.

The mapping exercise would be enhanced by supporting industrial businesses to adopt energy management systems that supply them with a granular understanding of their disaggregated load. It would also allow proactive engagement between industrial firms, energy market stakeholders, policy makers and agencies such as ARENA that could collaborate to plan demonstration projects for industrial heat pump deployment.

Given the significant additional, localised electrical load that would be associated with wide-scale deployment of heat pumps for process heat in Australia, careful integration with grid and with onsite and offsite renewable generation will be crucial.

189 New Zealand Ministry of Business, Innovation and Employment 2019, *Process heat in New Zealand*, New Zealand Government, Wellington.

Pilot and demonstration program for near-term opportunities

As low-temperature heat pump and MVR applications already have reasonably high underlying technological maturity, a near-term opportunity exists for pilots and demonstration projects to increase skills and experience integrating the technology into subsectors across manufacturing and food processing, and overcome 'technology inertia' that resists deployment of newer and less-familiar technologies.

Pilot studies and demonstrations are important to enable industry to begin the process of applied learning. Existing mechanisms, such as ARENA's knowledge sharing programs, are well placed to catalyse these activities with appropriate additional funding.

Some opportunities – such as using heat pumps for water heating – do not require major process change. Other process heat opportunities may require a major redesign. An opportunity exists for government (through a suitable agency, such as ARENA) to partner with industry to identify sites due for major process redesign or replacement in the next 2-5 years, which could integrate heat pumps.

It is recommended that a small selection of sites across a range of applications are chosen, to maximise the experience and lessons available through a program of pilots and demonstration. An example pilot and demonstration program is itemised in **Box 28**.

At present, only one of the six alumina manufacturing sites in Australia have committed to demonstrate MVR technology processes and only for evaporation processes, not digestion processes. Given MVR technology at alumina sites represents the largest opportunity for Australia to reduce emissions for process heat, there is a strong case for all sites piloting this technology simultaneously, rather than waiting 3-5 years for the testing at one site to be completed. This report suggests considering additional investment in MVR technology across all alumina sites as an immediate opportunity to reduce emissions.

The program would also provide a significant opportunity to integrate demand management and thermal storage into industrial process heat. Good heat pump system design incorporating thermal storage is especially important in the industrial sector. Paired with thermal storage, smart controls that allow integration with the electrical grid and renewables forecasting could optimise heat pump operation to match the availability of renewable energy. R&D could enable advanced controls and forecasting systems that will allow greater load flexibility and grid integration.

BOX 28: Example industrial heat pump pilot and demonstration program

A program of industrial heat pump pilots and demonstration projects through a suitable mechanism (such as ARENA), could demonstrate heat pump technology in a range of applications. Selection of sites across different industries and scales would allow a wide range of experience in heat pump deployment to be garnered. For example, a modestly sized program could include contributions to heat pump installations in food processing and manufacturing (Note: these values are illustrative only):

- Breweries: 5 small ($100,000 each) and 1 large ($2 million);
- Wineries: 5 small ($100,000 each) and 3 large ($200,000 each);
- Dairies: 10 small ($100,000 each) and 5 large ($400,000 each);
- Meat processing: 1 small ($200,000), 1 medium ($1 million) and 1 large ($2 million);
- Beverage: 5 small ($100,000 each) and 5 large ($300,000 each); and
- Non-alumina MVR: 4 sites ($1 million each) across different applications such as sugar, ethanol, chemical manufacturing.

Total: $15.8 million

Extending MVR technology pilots to all Australian alumina processors could add around another $50M to the program but could help drive widespread introduction of MVR to alumina processing, which would deliver large emissions reductions.

Research and development for medium term opportunities

Although heat pump technology is mature in many applications, targeted investment in R&D could build trust in the performance and economics of high temperature heat pumps, especially for large sites with potential for major emissions improvements. Ongoing R&D is also important to expand the benefits available from heat pumps in industrial settings and to broaden their application.

While Australia is likely to import industrial heat pump technology from overseas, ongoing R&D will support effective integration and adoption of emerging heat pump technology into Australian industrial settings. Targeted R&D into these areas will help accelerate uptake of advanced heat pump technology amongst industrial businesses here and support ongoing capability development.

Research undertaken for this report only identified two organisations bringing together researchers and industry to develop heat pump technology: the University of South Australia and ARENA. Increased support for R&D and testing at Australian universities to enable suppliers and designers to further develop heat pumps and MVRs will be critical, as will international knowledge sharing on R&D outcomes.

Specific opportunities for targeted R&D exist in the deployment of MVR technology into alumina processing. An R&D roadmap could allow coordinated effort between multiple industry players and academia. Establishment of a centre of excellence or innovation hub would further R&D to expand the application of MVR and reduce total installed costs. Examples of additional R&D include:

- Design reviews for energy productivity measures at alumina sites – for example, improved yields, improved red mud washing, and reduced water usage. Industry experts consulted for this report suggest that implementation of these measures is likely to yield up to 10% energy savings, reducing the cost of retrofitting MVR technology;
- Modelling of optimised heat recovery for the overall alumina plant, for example integration of heat pumps and MVRs with waste heat from the calcining process;
- Modelling and testing of optimised evaporator heat exchanger design when operating with MVR technology; and
- Modelling to determine best ways for MVR heating systems to integrate with variable renewable electricity supply, for example oversizing MVR systems to give higher production during high solar PV production hours.

BOX 29: R&D overseas

Japan is at the forefront for development of heat pumps to produce steam. Japan's Ministry of Economy, Trade and Industry has played a coordinating and funding role, for example regarding development and commercialisation of CO_2 heat pumps.

Japan's Central Research Institute of Electric Power Industry is also progressing research into steam and high temperature heat pumps. They have established an environmental test facility for heat pumps to improve their performance with a view to expanding their use.

Austria, France, Germany, Norway, the Netherlands, Switzerland, Spain, Korea and China are conducting experimental R&D on industrial heat pumps.[190] Much European heat pump research is currently focused on developing and demonstrating heat pump technology for applications requiring temperatures around 150-160°C, including steam generation, and integration into new industries such as starch and brick production. Other demonstration projects are assessing heat pump technology to deliver low-temperature heat at near-zero greenhouse gas emissions, and storing industrial heat to reduce costs. Pilot efforts are examining the use of natural refrigerants to deliver temperatures of up to 200°C.[191]

190 Arpagaus, C. 2020, *A2EP briefing: Advances in industrial heat pumps – Supplier update, suitable refrigerants and application examples in food & steam generation*, Australian Alliance for Energy Productivity, Sydney.

191 de Boer, R., Marina, A., Zuhlsdorf, B., Arpagaus, C., Bantle, M., Wilk, V., Elmegaard, B., Corberan, J., and Benson, J. 2020, *Strengthening industrial heat pump innovation: Decarbonizing industrial heat*, Technical University of Denmark, Lyngby, Denmark.

7.4.2 Supporting recommendations

Deployment at scale faces several challenges, including availability of skilled and experienced professionals, robust supply chains and financial barriers. Specific enabling actions could help industrial sector businesses understand and build the case to adopt heat pump technology – particularly the adoption of widespread metering and energy management systems (EnMS).

Improving energy management and data in industrial processes

A barrier to decision-making regarding adoption of efficient technologies lies in a lack of granular data and knowledge about on-site energy usage. Improved data and knowledge allow an effective business case for investment in efficient technology such as heat pumps. Improving energy usage data and management would also support broader opportunities in energy efficiency.

Action

	Activity	Actor
I2	**Enable improved energy management at Australian industrial sites, including:** **1. Funding a national program to roll out metering and sub-metering infrastructure across industrial sites; and** **2. Support the adoption of energy management systems.** Horizon: 1-5 years Areas: Deployment at scale	Commonwealth

Metering and sub-metering systems enable businesses to measure and manage their energy consumption, and properly consider the business case for new technology. Energy management systems empower manufacturers and industrial energy users to navigate the transition to net zero by taking control of their energy consumption.

Many manufacturing sites lack basic metering and sub-metering, and do not link energy data to other data streams necessary to estimate efficiency indicators. This makes it difficult to link energy use to other factors, which enables site managers to identify opportunities for energy efficiency and fuel switching. Real time sub-metering for gas is especially rare.

A national program to put metering and sub-metering in place and build capacity to provide useful insights and indicators across all manufacturing sites would empower manufacturers and food processors to better manage their current equipment. They could then work with experts to build the business case for moving to new technologies, including heat pumps for process heating. Pairing metering and sub-metering with EnMS can ensure that the energy savings opportunities are realised, as an EnMS facilitates action.

EnMS are relatively uncommon in Australia due to historically low energy prices. They can help manufacturers and food processors manage their energy consumption and identify opportunities in a range of energy-saving measures and business productivity improvements, including fuel switching to new technologies.

EnMS – including AS/NZS ISO 50001:2021 – are established to drive continuous improvement in an organisation's energy performance. While EnMS include policies, plans and processes, executive buy-in and a dedicated energy manager and team are crucial to delivering ongoing energy management improvements. When these are in place, companies can achieve a reduction in energy intensity of 3% or more each year, every year.[192]

Overcoming financial barriers

Near-term deployment of some heat pump technology could deliver immediate emissions reduction savings, and additional incentives could materially accelerate deployment. In particular, MVR technology could be deployed to rapidly deliver reductions in energy usage and emissions in a range of industries.

192 Energy Efficiency Council (EEC) 2020, *Navigating a dynamic energy landscape: a briefing for manufacturers*, EEC, Melbourne, p.16.

BOX 30: Tooheys' financial savings from strategic energy management

Tooheys Brewery supplies around 250 million litres of beer to Australians each year. Parent company Lion guzzles a lot of energy producing 600 million litres annually across five breweries. To tackle this, Lion has implemented strategic energy management practices.

With the support of expert advice facilitated by the NSW Government, and leadership from the executive team, Lion improved its energy management systems at its Tooheys Brewery in Lidcombe, New South Wales.

Lion already had some energy management practices, such as energy policies, energy saving targets against production (GJ/hectolitre), and energy monitoring systems at some sites. In 2020, the company developed:

- Online energy e-learning modules to help employees understand energy consumption at the brewery and learn ways to improve energy performance;
- Energy models to provide the site with quantitative tools to track daily energy consumption against targets, predict future energy consumption and detect when energy consumption drifts outside of expected levels; and
- An energy management guide for employees to learn about Lion's energy management practices and support adherence and continuous improvement.

As a result, Lion expected to achieve ongoing energy spend reductions of 3-5% each year.[193]

193 Energy Efficiency Council (EEC) 2020, *Navigating a dynamic energy landscape: a briefing for manufacturers*, EEC, Melbourne, p.15.

Action

	Activity	Actor
I3	**Consider actions to incentivise to industrial heat pump deployment, including:** **1. Reducing barriers to ERF participation, including new methods or guidance;** **2. Development of a co-investment scheme to assist industry to deploy heat pump and MVR technology; and** **3. Development of alternative methods of demonstrating emissions reductions where M&V is a significant barrier to scheme participation.** Horizon: 1-3 years Areas: Deployment at scale	Commonwealth (1-3) States and territories (2-3)

Well-designed financial incentives can help overcome financial barriers to deployment. Reducing barriers to participation in existing schemes could be a cost-effective way of incentivising deployment. In some cases, a co-investment approach might be needed.

For industrial heat pump technology, several policy mechanisms exist to assist with pre-commercial development and demonstration – including ARENA programs – but there does not appear to be a suitable mechanism to incentivise deployment of heat pumps – including MVR technology – amongst industrial sites. Stakeholder feedback has highlighted significant barriers to participation in the Emissions Reduction Fund (ERF).

Transaction costs for participation in ERF methods are high, with the cost of required measurement and verification steps sometimes negating the financial benefits that could accrue from creation of Australian Carbon Credit Units (ACCUs). ERF participation is also subject to high levels of uncertainty, which creates barriers to creating a bankable business case for deployment.

State-based energy savings schemes have also not yet significantly driven uptake of heat pump and deployment technology, with similar barriers regarding uncertainty and M&V costs.

Consideration could be given to actions to better incentivise wide-scale deployment of heat pumps, such as:

- Reducing barriers to participation in the ERF, such as development of a specific method for MVR technology, in the same style as the refrigeration and ventilation fans method, or introducing heat pump/MVR-specific guidance under an existing method;
- Developing methods for ACCU creation that allow for alternative demonstration of emissions reduction without formal M&V requirements where these activities would substantially reduce the benefit from ERF participation. This could also apply to state and territory energy savings schemes; and
- Developing a direct co-investment scheme between the Commonwealth and industrial entities that would share the upfront costs of installation, as well as the benefits – noting that the benefit of emissions reduction is largely a public benefit, rather than a private benefit to be captured by industry. State and territory governments could also be party to such a scheme to incentivise competitiveness of local industry.

While exact policy measures to incentivise heat pump deployment at scale in industry require further development, an effective program could help unlock emissions reduction, energy productivity and investment in Australian industry, supporting future industrial competitiveness.

A

Appendicies

GLOSSARY

Acronym	Description
A2EP	Australian Alliance for Energy Productivity
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABCB	Australian Building Codes Board
ACCUs	Australian Carbon Credit Units
ACEEE	American Council for an Energy Efficient Economy
ACT	Australian Capital Territory
AEF	Australian Energy Foundation
AEMO	Australian Energy Market Operator
AIRAH	Australian Institute of Refrigeration, Airconditioning and Heating
ARENA	Australian Renewable Energy Agency
AS/NZS	Australian / New Zealand Standard
ASHP	Air-source heat pump
BASIX	Building Sustainability Index (NSW)
BEIS	UK Department for Business, Energy and Industrial Strategy
BMWK	Federal Ministry for Economic Affairs and Climate Action (Germany)
BZE	Beyond Zero Emissions
CapEx	Capital expenditure
CBD	Commercial Building Disclosure program
CCA	Climate Change Authority
CEFC	Clean Energy Finance Corporation
CIE	Centre for International Economics
CNCC	Crows Nest Community Centre
CO_2e	Carbon dioxide equivalent
COAG	Council of Australian Governments
COP	Coefficient of performance
CRI	Commercial readiness indicator
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSR	Corporate social responsibility
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DISER	Department of Industry, Science, Energy and Resources
DRED	Demand response enabled device
E3	Equipment Energy Efficiency program
ECEEE	European Council for an Energy Efficient Economy
EEC	Energy Efficiency Council

Acronym	Description
EECA	New Zealand Energy Efficiency and Conservation Authority
EHI	Association of the European Heating Industry
EnDK	Intercantonal Energy Directors' Conference (Switzerland)
EnMS	Energy management system
EPC	Energy Performance Certificate (UK)
ERF	Emissions Reduction Fund
EU	European Union
FCAS	Frequency Control Ancillary Services
GBCA	Green Building Council of Australia
GDP	Gross domestic product
GEMS	Greenhouse and Energy Minimum Standards
GJ	Gigajoule
GSHP	Ground-source heat pump
GW	Gigawatt
GWP	Global warming potential
HCs	Hydrocabons
HEEUP	Home Energy Efficiency Upgrade Program
HFCs	Hydrofluorocarbons
HFOs	Hydrofluoroolefins
HPHWS	Heat pump hot water system
HPT TCP	Heat Pumping Technologies Technology Collaboration Programme
HTHP	High temperature heat pump
HVAC	Heating, ventilation and air conditioning
IEA	International Energy Agency
ISP	Integrated System Plan
JATL	Japan Air Conditioning Testing Laboratory
kW	Kilowatt
kWh	Kilowatt-hour
LPG	Liquefied petroleum gas
M&V	Measurement and verification
MEPS	Minimum energy performance standards
MIDAS	Market Informed Demand Automation Server (California)
Mt CO_2e	Millions of tonnes carbon dioxide-equivalent
MVR	Mechanical vapour recompression
NABERS	National Australian Built Environment Rating System
NatHERS	Nationwide House Energy Rating Scheme

Acronym	Description
NCC	National Construction Code
NEM	National Electricity Market
NSW	New South Wales
NYSERDA	New York State Energy Research and Development Authority
OpEx	Operational expenditure
p.a.	Per annum
PJ	Petajoule
PV	Photovoltaic
R&D	Research and development
RACE for 2030	Reliable, Affordable, Clean Energy for 2030 Cooperative Research Centre
RCAC	Reverse cycle air conditioner
RD&D	Research, development and deployment
REI	Renewable Energy Indicator (NABERS)
RET	Renewable Energy Target
RHI	Renewable Heat Incentive (UK)
RTO	Registered training organisation
SME	Small- and medium-sized enterprise
SRES	Small-scale renewable energy scheme
SRI	Smart readiness indicator (EU)
STCs	Small technology certificates
TCP	Technology Collaboration Programme (IEA)
TRL	Technology readiness level
UK	United Kingdom
US	United State of America
USD	US dollar
VHTHP	Very high temperature heat pump
VPP	Virtual power plant
VRE	Variable renewable energy
VRF	Variable refrigerant flow
VRV	Variable refrigerant volume
WEM	Wholesale Electricity Market (WA)
WDRM	Wholesale Demand Response Mechanism
WSHP	Water-source heat pump
ZERL	Zoned Energy Rating Label

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APPENDIX 1

List of policies and programs for heat pump deployment

Program/policy that supports heat pumps	Jurisdiction	Sector	Application	Area of opportunity	Status (as at March 2022)
Zero Net Carbon Homes program – Sustainability Victoria	Australia	Residential	Space heating Water heating	Experience & early deployment	Closed
Fairwater Living Laboratory (ARENA)	Australia	Residential	Space heating Space cooling	Experience & early deployment	Closed
GEMS	Australia	Residential Commercial	Space heating Space cooling	Regulation and standards	Open
E3 program	Australia	Residential	Space heating Water heating	Regulation and standards	Open
Zoned Energy Rating Label	Australia	Residential	Space heating Space cooling	Regulation and standards	Open
Plumbing industry engagement pilot (Australian Energy Foundation)	Australia	Residential	Water heating	Experience & early deployment	Open
Home Energy Efficiency Upgrade Program (HEEUP) (Brotherhood of St Laurence)	Australia	Residential	Water heating	Deployment at scale	Closed
The complete guide to choosing your perfect hot water heat pump (Australian Energy Foundation)	Australia	Residential	Water heating	Awareness	Open
Queensland's PeakSmart program	Australia	Residential	Space heating Space cooling	Deployment at scale	Open
State/territory energy efficiency schemes: *Victoria*, *New South Wales*, *Australian Capital Territory*, *South Australia*	Australia	Residential Commercial	Space heating Space cooling Water heating	Deployment at scale	Open
Renewable energy target (RET)	Australia	Residential Commercial	Water heating	Deployment at scale	Open
NABERS	Australia	Commercial	Space heating Space cooling Water heating	Awareness	Open
Green Star	Australia	Commercial	Space heating Space cooling Water heating	Awareness	Open

Program/policy that supports heat pumps	Jurisdiction	Sector	Application	Area of opportunity	Status (as at March 2022)
Alcoa feasibility study	Australia	Manufacturing	Industrial heating	Experience & early development	Open
Market Informed Demand Automation Server (MIDAS)	California (US)	Residential	Space heating Space cooling Water heating	Integration Deployment at scale	Open
Market transformation roadmap for energy efficient equipment in the building sector	Canada	Residential	Space heating	Strategy Deployment at scale	Open
Subsidies for installation of air-source heat pumps	China	Residential	Space heating	Deployment at scale	Closed
European Heat Pump Association	Europe	Residential Commercial	Space heating Space cooling Water heating	Regulation and standards Awareness	Open
Smart readiness indicator	EU	Residential	Space heating Space cooling Water heating	Integration Deployment at scale	Open
Ecodesign standards	EU	Residential	Space heating Space cooling	Regulation and standards	Open
Heating system inspections	France	Residential	Space heating	Regulation and standards	Open
German Heat Pump Association (BWP)	Germany	Residential	Space heating	Awareness	Open
Global Cooling Prize	Global	Residential	Space cooling	R&D	Closed
Heat Pumping Technologies (HPT) Technology Collaboration Programme (TCP) (IEA)	Global	Residential Commercial	Space heating Space cooling Water heating	R&D	Open
Japan Air Conditioning and Testing Laboratory (JATL)	Japan	Commercial	Space heating Space cooling	Regulation and standards	Open
Japan Refrigeration and Air Conditioning Industry Association (JRAIA)	Japan	Commercial	Space heating Space cooling	Awareness	Open
Central Research Institute of Electric Power Industry	Japan	Manufacturing	Industrial heating	R&D Regulation and standards	Open
Ministry of Economy, Trade and Industry (METI) coordination & funding	Japan	Manufacturing	Industrial heating	R&D	Open

Program/policy that supports heat pumps	Jurisdiction	Sector	Application	Area of opportunity	Status (as at March 2022)
Top Runner program	Japan	Residential Commercial	Space heating Space cooling Water heating	Regulation and standards	Open
Tax credits for replacement of oil heaters with heat pumps	Sweden	Residential	Space heating	Deployment at scale	Closed
Tax reductions for labour associated with heat pump installations	Sweden	Residential	Space heating	Deployment at scale	Closed
Technology procurement policy (1980s)	Sweden	Residential	Space heating	R&D	Closed
National Board for Consumer Disputes	Sweden	Residential	Space heating	Regulation and standards Awareness	Open
Swedish Refrigeration and Heat Pump Association (SKVP)	Sweden	Residential	Space heating	R&D	Open
WPesti	Switzerland	Residential	Space heating Space cooling	Regulation and standards	Open
Swiss Heat Pump Association (FWS)	Switzerland	Residential	Space heating	Regulation and standards Awareness	Open
Renewable Heat Incentive	UK	Residential	Space heating Water heating	Deployment at scale	Open
Heat and buildings strategy	UK	Residential Commercial	Space heating	Strategy	Closed
Ten point plan for a green industrial revolution	UK	Residential	Space heating	Strategy	Closed
Future Buildings Standard	UK	Commercial	Space heating	Strategy	Open
Green homes grant	UK	Residential	Space heating	Deployment at scale	Closed
Microgeneration Certification Scheme	UK	Residential Commercial	Space heating Space cooling Water heating	Awareness	Open
European Certified Heat Pump installer programme (EUCert)	UK	Residential Commercial	Space heating Space cooling Water heating	Awareness	Open

Program/policy that supports heat pumps	Jurisdiction	Sector	Application	Area of opportunity	Status (as at March 2022)
Initiative for Better Energy, Emissions and Equity	US	Residential	Space heating Water heating	R&D Regulation and standards Deployment at scale	Open
Renewable Thermal Collaborative	US	Manufacturing	Industrial heating	R&D Experience & early development	Open
Heat pump planner (NY State Energy Research and Development Authority)	US	Residential	Space heating Space cooling	Awareness	Open

APPENDIX 2

The *Heat Pump Energy and Emissions Savings Model*

A2.1 Understanding the worksheets

The *Model* is a Microsoft Excel spreadsheet with several linked worksheets and background data from various sources.

The visible worksheets are:

- **Cover page:** includes the revision history and brief overview of the *Model*;
- **Dashboard:** allows a user to make changes to key variables for major areas of heat delivery. It also presents graphs of reductions in final energy use and greenhouse gas emissions to 2050; these graphs are presented for each service relative to the baseline scenario used. The services include:
  - Residential space heating and water heating;
  - Commercial sector heat; and
  - Industrial heat supplied at temperatures up to 250°C;
- **Combined charts:** graphs of net annual and cumulative changes in final energy and emissions for all three sectors to 2050; and
- **Combined summary:** presents the data behind the graphs in the 'Combined charts' worksheet.

The hidden worksheets include:

- **Four calculation worksheets:** presents the calculations for each service and sector underpinning the **Dashboard** models. Data in these workbooks can be modified by an advanced user in any way, overriding the simplified approaches used for the **Dashboard**. For example, year by year changes in demand, efficiencies etc. can be specified. For example, a rapid increase in heat pump penetration over a few years can be entered to explore annual and cumulative effects of programs that aim to result in high impact over a short period of time;
- **AEMO GHG:** presents the annual emission intensity of grid electricity based on the AEMO 'Central' and 'Step Change' Integrated System Plan scenarios. The values can be changed for each year to explore different scenarios;
- **Comm data, Ind Data, Res End Use 2021:** presents the base year data and service efficiencies used in the calculations for each service and sector underpinning the **Dashboard** models. The values in these worksheets are linked to the earlier worksheets, so changes can be made here, or overridden by entering data in the earlier worksheets;
- **Res Relative Efficiencies, Res WH STCs, Comm Working:** presents early analysis and approaches to modelling. The final *Model* utilised a simpler approach which is based on the early analysis presented in this worksheet. These include state and climate zone level data for residential heating and hot water, and a more detailed sub-sector approach for the commercial sector. This worksheet is not linked to the previous worksheets; and
- **Data dictionary:** provides brief details and rationales for values of variables used in the *Model*. This dictionary is also found in *Appendix 2.4*.

A2.1.1 Using the *Model*

A **baseline scenario** for final energy use is created as part of the *Model*. This baseline scenario accounts for final energy used for delivery of heat from each relevant energy source. The baseline applies to each service and sector. The **base year** final energy by energy source is derived from the DISER Australian Energy Statistics 2020 'Table A' spreadsheet. This spreadsheet provides sector energy consumption for 2018-19 and is assumed to apply to the 2020 calendar year. This assumption is made to avoid the inter-annual variations caused by the COVID pandemic. Updated data can be entered when available. However, short-term complications due to the pandemic make updating data challenging and potentially misleading with regard to future trends.

Future demand in the baseline scenario is managed in the Dashboard by adjusting '% growth' and 'efficiency factor %'. '% growth' is a fixed percentage of the previous year's demand to estimate each year's demand and is applied to all forms of energy. 'Efficiency factor %' reflects overall improvement in efficiency of delivery of heat for the sector. 'Efficiency factor %' refers to overall efficiency improvement across the economy (i.e. energy productivity). Future demand in the baseline scenario is roughly equal to 0% as efficiency improvement roughly offsets economic growth across sectors. This figure can be updated within the *Model* spreadsheet.

The **proposed policy-driven rate of change in penetration of heat pumps delivering heat** for the service/sector is then specified in the Dashboard. This factor modifies the amounts of heat delivered by each energy source due to changed penetration of heat pumps. For example, a factor of 3% per annum means the previous year's heat supplied by gas is reduced by 3% of year 1, meaning the change is linear. For example, 10 years at 3% is 30% change, not 3% change from each previous year. This changes the amount of final energy provided by gas and reflects the reduction in energy from gas heating as it's replaced by heat pumps.

The **impact on electricity of switching heating to heat pumps differs from the other energy sources**. This is due to two factors, which must each be calculated:

1. First, the *net impact* of shifting from resistive electric heating to heat pump heating results in a reduction in electricity when heat pump penetration increases; and
2. Second, the replacement of heating provided by other energy sources with heat pumps results in an increase in electricity consumption.

Because of the presence of these two factors, the efficiencies of heat pump and resistive electric heaters are set separately.

The **assumed efficiencies of all energy sources** are shown in the **Dashboard**. These values can be modified by the user. As noted above, efficiencies of heat pumps are entered separately from resistive – or existing technology – electric heat sources. At present it is not possible to vary the efficiency over time.

The *Model* reports changes in energy use and emissions from the shares of heat pumps in the base year.

NOTE: default greenhouse gas emission factors in the DASHBOARD are extracted from a later worksheet, as outlined above. The user can enter alternative values in the dashboard to override these or can go to the detailed worksheets where year-by-year values for emission factors can be changed; these will then drive the dashboard calculations.

A2.2 Using the *Model* to explore proposed scenarios and more

DCCEEW asked for several scenarios to be explored. These include:

- A **baseline scenario**; and
- **Time-based scenarios** in which penetration of 100% use of heat pumps is achieved, including:
  - Late adoption, 100% penetration starting from 2040;
  - Linear to net zero 2050, (average 3.3% increase per annum);
  - Linear to net zero including 2% extra energy efficiency; and
  - Super charged deployment, 100% penetration in 10 years (average 10% per annum).

The **baseline scenario** includes final energy and shares of energy provided by existing sources. These outputs are driven by:

1. The net result of the overall growth trend due to economic growth, structural change and population growth; and
2. 'Efficiency improvement', which is the overall improvement in energy productivity at an economy level.

This shows how changes in the emission intensity of energy sources, particularly electricity, change emissions associated with heat supply. The *Model* includes two options for trends in electricity emission intensity: AEMO's 'Central' and 'Step change' scenarios, as shown below. Three core **time-based scenarios** exist in the *Model* with varying rates of transition towards 100% use of heat pumps for applications for which heat pumps can be applied:

1. Late Adoption;
2. Linear to 2050; and
3. Supercharged 100% in 10 years.

These scenarios can be created and compared with the baseline scenario by entering different values in the 'heat pump penetration' cell (corresponding to the above scenarios):

1. 10%;
2. 6.67%; and
3. 5%.

Two additional scenarios are modelled. A variant of the 'linear to 2050' scenario is modelled with additional energy efficiency improvements, to explore the effects of additional, contemporaneous improvements to energy efficiency that is likely to occur when a heat pump is retrofitted – such as addition of insulation or re-design of a process that the heat pump powers. An additional 'slow industrial growth' scenario is modelled in the industrial sector only – reflecting a potential for slower progress in industrial heat pump deployment, based on the possibility of lower commercial maturity and/or low capital investment conditions for heat pumps in the industrial sector.

Some examples of scenarios or sensitivity studies that can be explored, and how this can be done, include:

- Rapid rollout over a period of years, or in different blocks of years, in one or more sectors. This scenario can be modelled by manually entering year-by-year rates of change in the '....calcs' worksheets;

- Different levels of emission intensity for electricity. This scenario can be modelled by replacing the emission intensity values in one of the existing emission intensity rows in the 'AEMO GHG' worksheet; and
- Efficiencies of utilisation for different technologies or energy sources. This scenario can be changed in the '**Dashboard**' worksheet.

Some potentially relevant messages from the *Model* include:

1. In the near term, replacing inefficient electric equipment with heat pumps offers substantial annual emission reductions but, when emission intensity of electricity is low, the reductions reduce. However, this measure may reduce factors that are not addressed in this *Model* such as peak demand, especially if thermal storage and demand response capability is included. Behind-the-meter PV system generation can also be matched with the heat pump to provide the required demand response;
2. In general, earlier action leads to larger cumulative emission reductions over time. This is due to a greater number of years of savings and reductions in emission intensity of electricity driving heat pumps over a greater period of time; and
3. The relative efficiencies of an existing gas appliance and a heat pump are critically important for the business case: if the actual efficiency of gas appliances is lower than assumed, then the business case for heat pumps is undermined because heat pump systems will be oversized to match the assumed efficiency of the previous system. Our knowledge of real-world efficiencies of gas equipment and heating systems is poor. and Most studies tend to assume equipment efficiency is higher than it really is, and that the system efficiency is similar to the equipment efficiency, whereas it can be substantially lower.

A2.3 Strengths and limitations of the *Model*

The *Model* estimates outcomes based on changes to the amounts of thermal energy delivered by varying combinations of energy sources and technologies. This approach takes into account (estimated) system efficiencies associated with delivery of heat rather than applying an 'efficiency factor' to end-use energy consumption. Therefore, it requires users to consciously select values for system efficiencies and allows them to explore the sensitivity of outcomes to changes in this value. The importance of this factor is discussed in 'potentially relevant messages' above in point 3.

Establishing the baseline energy use for low temperature heating has proven to be difficult, with the Australian Energy Statistics not providing the required level of detail. In this case, assumptions have been applied to energy consumption data from the Australian Energy Statistics 2020, 'Table A'.

Additional limitations of the *Model* include:

- Options for reducing the amount of heat required are not specifically examined. These options include changes in end-use process efficiency such as water-efficient showerheads, insulation of process equipment, other options that reduce the amount of heat required to deliver a service, or progressive improvement in heat pump average COP;
- The scenarios consider a variety of possible trends in demand that could reflect factors such as growth in population and gross domestic product (GDP), but these scenarios may not eventuate;
- Other zero- or low-carbon options for providing heat or high temperature heat for industry are not explored. These options include heat recovery, other ways of energy recovery, microwaves, improvement in thermal efficiency of buildings, etc. These factors may be more cost-effective or practical in many situations, and can be addressed by:
  - Changing the Baseline '% growth' and/or 'efficiency factor%' in the **Dashboard**; or
  - By changing the efficiency values for energy sources;
- Consideration of options to utilise 'waste heat' from many sources is limited to adjustment of the efficiency of heat pumps. This is based on recognition that higher input temperatures improve the efficiency – as reflected by the COP – of heat pumps. There are large amounts of 'waste heat' available at many sites, especially in industry, from refrigeration, exhaust air streams, compressed air equipment etc. It is possible to build sub-models that analyse such situations and provide an output value that could be fed into this *Model*; and
- Changes at a sectoral or activity/service level are considered. In practice, effective policies and programs may target sub-groups which likely to have disproportionate cost-effective energy saving potential. This is due to old equipment nearing replacement, or being extremely inefficient. These sub-groups include:
  - Users of high-cost energy sources, e.g., resistive electricity, oil, LPG; and
  - High energy intensity users. For example, in the commercial and residential sectors, the 5% highest energy intensity consumers use around 15% of the sector's energy.

A2.4 Data dictionary for the *Model*

The following table provides further information on each of the *Model's* variables.

Residential space heating		
Inputs*	**Default**	**Description**
Growth Rate (% pa)	0%	'test value': User to set for reference scenario. Overall trend in economy, structural change and population. Annual growth rate for the sector. Modelling for this report uses 2.6% per annum as the annual factor.
Efficiency Factor (% pa)	0%	'test value': User to set for reference scenario. Economy level rate of improvement in energy productivity. Annual improvement in energy efficiency. Modelling for this report uses 2.1% per annum as the annual factor.
HP Penetration (% pa)	0%	This drives rate of increase in replacement of delivered heat by HP. 'test value': User to set based on adoption scenario.
HP Efficiency (COP)	5	This factor is used to estimate the net increase in electricity consumption when a gas heater is replaced by a heat pump.
AC Ducted Efficiency (COP)	3.1	Present MEPS value for ducted HP up to 39 kW output see MEPS Legislation Schedule 1.[194] Many new heat pumps have significantly higher COPs than MEPS but also have ducting losses that impact on overall efficiency.
AC Non-Ducted Efficiency (COP)	3.66	MEPS value for up to 4 kW non-ducted. 4-10 kW is 3.22. Many split systems have much higher COPs. However, clogged filters can reduce performance if not cleaned.
Electric Resistive Efficiency (COP)	0.9	'test value'. In theory, efficiency is 100% but thermostat deadband, temp stratification etc. reduces real world efficiency.
LPG Non-Ducted Efficiency (COP)	0.73	Australian Gas Association efficiency for 3-star heater.
Mains Gas Ducted Efficiency (COP)	0.73	Australian Gas Association efficiency for 3-star heater. In practice, duct losses alone are 12-50%[195] and there are other issues such as increased air leakage, clogged filters, and heating larger areas than necessary. This means this efficiency value is conservative and likely to over-state the efficiency of gas systems
Mains Gas Non-Ducted Efficiency (COP)	0.73	Australian Gas Association efficiency for 3-star heater.
Grid Emissions Scenario (ISP)		Based on AEMO 'Central' and 'Step Change' scenarios in 2020.
Gas GH Factor (Mt CO_2e/PJ)	0.056	National Greenhouse Account Factors Workbook Scope 1+3 approximate Australian average. At this stage of development, this does not include leakage from low pressure distribution and behind-the-meter.
LPG GH Factor (Mt CO_2e/PJ)	0.07	This is an approximation for oil – LPG scope 1+3 is 0.064. Oil/LPG is a minor and uncertain size contributor to total heating energy.
*leave blank for default		Wood has not been included. In the factors workbook, it has a very low emissions factor of 0.0012. However, many wood heaters emit significant non-Kyoto emissions, and may involve land clearing. Further, much of the transition from wood is driven by urban air pollution issues, so there is a case to consider that shifts from wood heating to heat pumps would happen regardless of policy action, so it is part of the baseline. Also, use of a HP instead of other options is likely to be the lowest emission option.

194 Australian Government 2019, *Greenhouse and Energy Minimum Standards (Air Conditioners up to 65kW) Determination 2019*, Australian Government, Canberra.

195 Palmer, G. 2008, *Field study on gas ducted heating systems in Victoria*, Master's thesis, RMIT, Melbourne.

Residential hot water		
Inputs*	**Default**	**Description**
Growth Rate (% pa)	0%	'test value': User to set for reference scenario. Annual growth rate for the sector. Modelling for this report uses 2.6% per annum as the annual factor.
Efficiency Factor (% pa)	0%	'test value': User to set for reference scenario. Annual improvement in energy efficiency. Modelling for this report uses 2.1% per annum as the annual factor.
HP Penetration (% pa)	0%	This drives rate of replacement of delivered heat by HP. 'test value': User to set based on adoption scenario.
HP Efficiency (COP)	3.5	Annual COP for Sanden/Stiebel Eltron heat pumps including allowance for heat loss from storage tank. Estimates based on STCs are shown in 'Res Effs' worksheet. Actual efficiencies are sensitive to water usage and tank losses.
Electric – Med/Large Efficiency (COP)	0.9	'test value' roughly equivalent to 'reference HWS' in AS 4234: 2008 based on approximately 200L/day HW use, which is higher than typical usage in Australia at 120L/day, so the actual efficiency is lower.
Electric Small Efficiency (COP)	0.9	
Gas Instant LPG Efficiency (COP)	0.6	'test value' roughly equivalent to 'reference HWS' in AS 4234: 2008 based on approximately 200L/day HW use which is higher than typical usage in Australia at 120L/day. The actual efficiency is higher as instant units do not have standby losses from tank and pilot lights, though they do have 'start-up' losses.
Gas Instant Mains Efficiency (COP)	0.6	As above.
Gas Storage LPG Efficiency (COP)	0.6	'test value' roughly equivalent to 'reference HWS' in AS 4234: 2008 based on approximately 200L/day HW use which is higher than typical usage in Australia at 120L/day, so the actual efficiency is lower due to standby heat loss from tank and pilot light spread over lower HW usage.
Gas Storage Mains Efficiency (COP)	0.6	As above
Solar Electric Boosted Efficiency (COP)	0.9	Generous marginal efficiency for electric boosting of a solar HWS
Solar Gas Boosted Efficiency (COP)	0.6	As for other gas options
Grid Emissions Scenario (ISP)		Based on AEMO 'Central' and 'Step Change' scenarios.
Gas GH Factor (Mt CO_2e/PJ)	0.056	Greenhouse Factors Workbook Scope 1+3 approximate Australian average. Note that this does not include leakage from low pressure distribution and behind-the-meter.
LPG GH Factor (Mt CO_2e/PJ)	0.07	This is an approximation for oil – LPG scope 1+3 is 0.064. Oil/LPG is a minor and uncertain size contributor to total heating energy.
*leave blank for default		

Commercial buildings (NOTE: final energy data from DISER Table, but diesel is reduced from 30PJ to 10PJ. It is not clear how much oil is used for heat in this sector.)		
Inputs*	**Default**	**Description**
Growth Rate (% pa)	0%	'test value': User to set for reference scenario. Annual growth rate for the sector. Modelling for this report uses 2.6% per annum as the annual factor.
Efficiency Factor (% pa)	0%	'test value': User to set for reference scenario. Annual improvement in energy efficiency. Modelling for this report uses 2.1% per annum as the annual factor.
HP Penetration (% pa)	0%	This value drives rate of replacement of delivered heat by HP. 'test value': User to set based on adoption scenario.
HP Efficiency (COP)	3.5	'test value': very wide range of performance – units with cooling towers much more efficient, distribution losses from ducts, pipes and fan/pump energy can be high.
Resistive Efficiency (COP)	0.9	As above
Gas Efficiency (COP)	0.65	'test value': while operating efficiency is higher, intermittent and part load operation, standby and distribution losses can be significant.
Oil/LPG Efficiency (COP)	0.65	Assumed same as gas
Grid Emissions Scenario (ISP)		Based on AEMO 'Central' and 'Step Change' scenarios.
Gas GH Factor (Mt CO_2e/PJ)	0.056	Greenhouse Factors Workbook Scope 1+3 approximate Australian average. Note that this does not include leakage from low pressure distribution and behind-the-meter.
Oil/LPG GH Factor (Mt CO_2e/PJ)	0.07	This is an approximation for oil – LPG scope 1+3 is 0.064. Oil/LPG is a minor and uncertain size contributor to total heating energy.
*leave blank for default		

Industrial		
Inputs*	**Default**	**Description**
Growth Rate (% pa)	0%	'test value': User to set for reference scenario. Annual growth rate for the sector. Modelling for this report uses 2.6% per annum as the annual factor.
Efficiency Factor (% pa)	0%	'test value': User to set for reference scenario. Annual improvement in energy efficiency. Modelling for this report uses 2.1% per annum as the annual factor.
HP Penetration (% pa)	0%	This drives rate of replacement of delivered heat by heat pump. 'test value': User to set based on adoption scenario.
HP Efficiency (COP)	3.5	'test value' based on residential HPHWS. Efficiencies vary widely with design and refrigerant, as well as variation in system losses, e.g. point of use heat pump has lower distribution losses than central heat pump.
Resistive Efficiency (COP)	0.9	'test value'
Gas Efficiency (COP)	0.6	'test value': while operating efficiency is higher, intermittent and part load operation, standby and distribution losses can be significant.
Oil/LPG Efficiency (COP)	0.6	As for gas
Coal Efficiency (COP)	0.5	'test value' – assume older, higher thermal inertia, less efficient than gas boilers.
Bio-Energy (COP)	0.4	Estimated
Grid Emissions Scenario (ISP)		Based on AEMO 'Central' and 'Step Change' scenarios.
Gas GH Factor (Mt CO_2e/PJ)	0.056	Greenhouse Factors Workbook Scope 1+3 approximate Australian average. Note that this does not include leakage from low pressure distribution and behind-the-meter.
Oil/LPG GH Factor (Mt CO_2e/PJ)	0.07	This is an approximation for oil – LPG scope 1+3 is 0.064. Oil/LPG is a minor and uncertain size contributor to total heating energy.
Coal GH Factor (Mt CO_2e/PJ)	0.09	Approx Greenhouse Factors Workbook value
Bio-Energy GH Factor (Mt CO_2e/PJ)	0.004	Approx Greenhouse Factors Workbook value
*leave blank for default		

APPENDIX 3

Findings from consultation undertaken for this report

A survey was administered to individuals who submitted an expression of interest (EOI) to receive updates or provide feedback on the heat pumps project. The 52 individuals – who were largely EEC and A2EP members and stakeholders – responded to the survey, were:

- Energy services providers;
- Engineers;
- Facilities managers;
- Consultants;
- Representatives from local and state governments; and
- Employees of social enterprise.

Respondents were asked to rate barriers to heat pump adoption and opportunities for encouraging heat pump adoption on a scale of 1 to 8, with 1 being equivalent to the greatest barrier or opportunity, and 8 being the smallest.

Barriers suggested within the survey included:

- End-user awareness and/or perceptions;
- Installer awareness, perceptions and/or skills gaps;
- Insufficient standards;
- Inadequate supply chains;
- Lack of, inadequate and/or insufficient incentives;
- Space requirements;
- Upfront costs; and
- Other (please specify).

A3.1 Barriers

As **Figure 29** shows, respondents indicated that the top three barriers to heat pump adoption were:

1. End-user awareness and/or perceptions;
2. Installer awareness, perceptions and/or skills gaps; and
3. Up-front costs.

The top three barriers identified by respondents were mirrored by interviewee respondents and addressed in Sections 5, 6 and 7 as opportunities for improvement in Australia.

'Other' barriers included:

- Lack of smart grid capability for tariff optimisation and load management;
- Sound illustration of business case compared to gas or electric resistance heating;
- Return on investment;
- Limited consultancy knowledge;
- Lack of technical support from the few available suppliers of larger scale heat pumps (i.e., above 200 kW); and
- Lack of successful case studies from various sectors.

Sector-specific barriers included:

- Residential buildings: End-user awareness and installer awareness;
- Commercial buildings: End-user awareness and upfront costs;
- Manufacturing: End-user awareness and installer awareness; and
- Agriculture: End-user awareness and installer awareness.

Improving the awareness of end-users and installers was identified as a major opportunity for overcoming existing barriers and improving heat pump adoption across the sectors. Across the sectors, consumers and end-users tend to be unfamiliar with heat pumps and do not ask for them, and installers are hesitant to recommend them.

What are the biggest barriers to the adoptions of heat pumps in Australia?

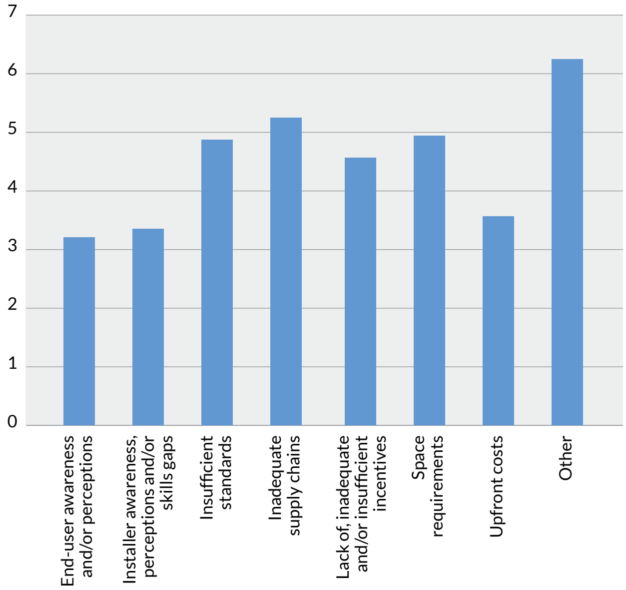


Figure 29 Perceived barriers to the adoption of heat pumps in Australia (According to survey respondents) A lower rating indicates a greater barrier.

Suggested opportunities included:

- End-user education;
- Installer education, skills and training;
- Improved standards;
- Development of local supply chains;
- Government incentives;
- Minimum standards for space heating/cooling and/or water heating/cooling in building design and/or performance; and
- Other (please specify).

Findings from the industry survey indicate that policy measures should be targeted at both installers and end users. The broader research demonstrates that a wider aspiration towards market transformation is necessary to ensure quality and performance, develop supply chains, and incentivise adoption by end-users.

A3.2 Opportunities

As shown in **Figure 30**, respondents indicated that the top three opportunities for encouraging the adoption of heat pumps in Australia were:

1. End-user education;
2. Installer education, skills and training; and
3. Government incentives.

As these sentiments were echoed by interviewees, they were included as options for realising the opportunity within this report.

'Other' opportunities included:

- Improve ease of access to rebates;
- Provide publicly available detailed performance curves;
- Improve viable natural refrigerant options;
- Increase the pool of knowledgeable trainers;
- Develop publicly available case studies; and
- Improve accuracy of specified performance data.

What is the biggest policy opportunity for encouraging the adoption of heat pumps in Australia?

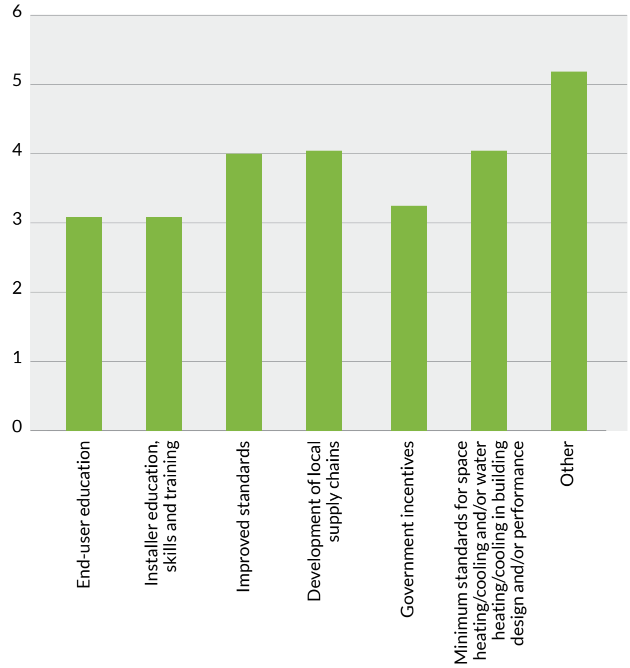
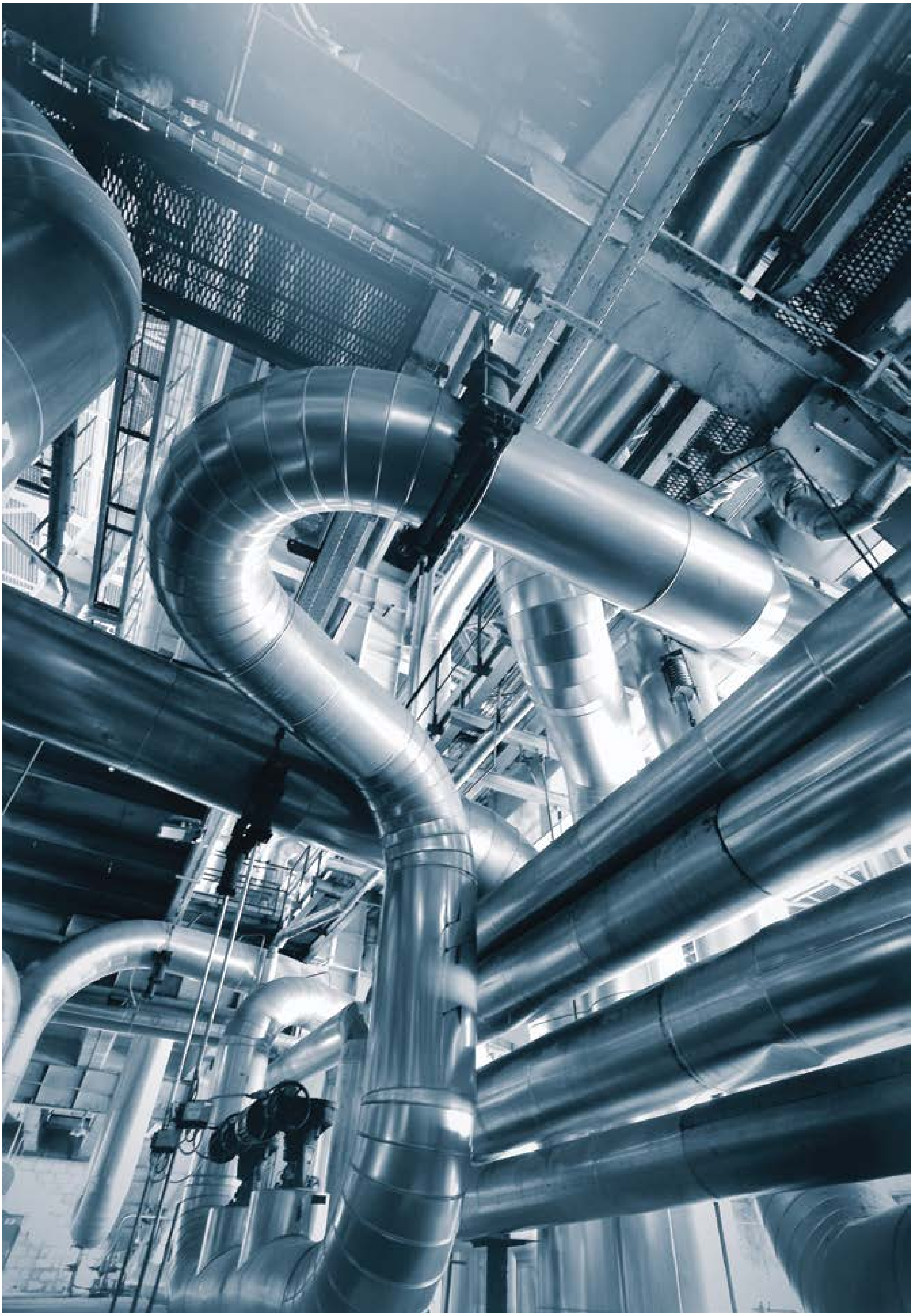


Figure 30 Perceived opportunities to the adoption of heat pumps in Australia (According to survey respondents) A lower rating indicates a greater opportunity.



Notes

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