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Hot prospect

Heat pumps: the new must-have home appliance?

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HOT PROSPECT

After a difficult start, heat pumps are rapidly gaining traction in Australian homes, as **Sean McGowan** reports.

In October 1973, an oil embargo called on by the Organisation of Arab Petroleum Exporting Countries (OAPEC) quadrupled the global price of oil in the space of just six months.

Later referred to as the first oil "shock" or "crisis", the embargo had many short- and long-term effects on the global economy. Among them was a greater interest in alternative energy sources and new technologies.

These included the development of solar hot water heaters in Israel, and ground-source heat pumps across Europe.

Although heat pumps quickly became popular on the back of their energy-efficiency promise, when OAPEC lifted the embargo and oil prices fell back to normal levels, they were no longer such a big money-saver.

But it wouldn't be for long.

By 1979 when the second "oil shock" hit the world economy as a result of the Iranian Revolution, heat pumps were back in vogue. They garnered particularly strong support in Sweden, where an appetite for renewable energies combined with a market incentive program saw the heat pump market flourish.

Their popularity has continued to grow over the decades since, with two types of heat pump systems commonly in use across Europe today.

"Central Europe uses mostly hydronic heat pumps, while in northern and southern Europe, air-to-air heat pumps are the most popular applications," says Andrea Voigt, director general at the European Partnership for Energy and the Environment (EPEE).

BY ANY OTHER NAME

Here in Australia, heat pumps have been used for some time – even if the technology has been recognised as something else.

For instance, reverse-cycle air conditioners that provide cooling and heating are a form of heat pump, and dedicated heat pumps are used for domestic hot water heating. They are also an emerging technology in the industrial sector, where they can be used to recycle low-temperature water heat to a higher heat for industrial processes.

But as Dr Paul Bannister, F.AIRAH, explains in a series of articles penned on behalf of Automatic Heating, the technology has been around for as long as we've had refrigeration.

"A heat pump is just a refrigerator in reverse," says Bannister.

"In a refrigerator, we extract heat from something we want to cool and reject that heat to the environment. In a heat pump, we extract heat from the environment and add that heat to something we want to heat."

The components are identical: two heat exchangers (one evaporator and one condenser), a compressor and an expansion valve.

"If you have an air conditioner that you use for heating in winter (reverse-cycle air conditioner) then you are using a heat pump," says Bannister. "The air conditioner is extracting heat from the cool outside air and bringing it into the house via the heat pump cycle."

A JOB FOR FRIDGIES OR PLUMBERS?

Given that most heat pumps in Australia are used to replace old gas-fired or electric domestic hot-water units, plumbers are typically the ones found installing such systems.

Both Stiebel Eltron and Sanden International report that no refrigeration or air conditioning knowledge is required to install their hot water heat pumps. The refrigeration system in their units is fully sealed.

"Some knowledge is required, however, by those specifying the products as a solution," says Fletcher.

"Being a refrigeration system at its core, the main requirement is the need for proper airflow in the case of air-source heat pumps – and avoiding the potential for recirculation of discharge air back into the unit, which will degrade performance."

THERMODYNAMICS AT WORK

According to Alan Pears, senior industry fellow at RMIT, a key factor underpinning the operating of heat pumps is that thermodynamics work from a base temperature of -273°C or absolute zero (the temperature of outer space).

"We need to understand that even cold air or water actually contains a lot of thermal energy," says Pears.

"And all things being equal, if you increase the pressure of a gas, you increase its temperature. If you remove heat from a hot gas (under the right conditions) it condenses into a liquid – just like the humid air from your clothes dryer condenses on the cold surfaces in the laundry."

A heat pump works by absorbing heat at the evaporator. This gas is pressurised by the compressor and as a consequence its temperature increases. Heat is then removed at the condenser, and the gas condenses to a liquid, still at high pressure.

The refrigerant then passes through a valve, depressurising and cooling – like the spray from an aerosol can. It absorbs heat again in the evaporator.

Since a heat pump just shifts and concentrates heat, it can offer very high efficiencies.

"Space-heating heat pumps can be over 500 per cent efficient," says Pears. "That is, the electricity input is less than a fifth of the amount of heat transferred."

With such high efficiencies possible, it's little wonder that heat pumps are now attracting more attention here in Australia.

> An all-electric home can now be both comfortable and affordable

THE LOCAL MARKET

A number of companies are driving the emerging heat pump market in Australia, including Automatic Heating, Sanden International and Stiebel Eltron – the last of these having developed and produced heat pumps in Germany since 1976.

According to Stiebel Eltron's national product manager Darren Fletcher, the uptake of heat pumps in Australia was once hindered by the poor performance of certain units.

"Some manufacturers and distributors in Australia, new to the technology 10 to 14 years ago, made design mistakes, provided lower quality products, oversold the capabilities of their systems and provided poor customer service," Fletcher says.

"Increased disappointment from unmet expectations then caused category damage to the technology for some time."

However, he says the recent rise in energy costs – especially natural gas prices – and Australia's push towards renewable energy has caused a resurgence of heat pumps in the local market.

"Rising gas prices are making Australian consumers think a little more when deciding upon heating, cooling and hot water appliances," he says. "And the market has worked out that a gas connection is not necessary – an all-electric home can now be both comfortable and affordable."

Domestic hot water heat pumps are becoming a substitute for traditional electric and gas water heaters. They may even garner a government

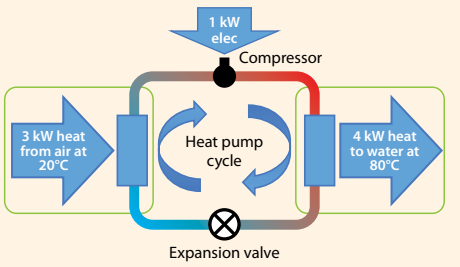
UNDERSTANDING HEAT PUMP EFFICIENCY

Normally when we think of efficiency, we think of it as a percentage of the energy we put into an appliance. Only some of it provides a useful output, the rest is wasted.

Thus we talk about a boiler being 90 per cent efficient – because only 90 per cent of the fuel energy input ends up as useful output heat, with the rest being lost via the flue or via radiant and convective losses from the boiler.

By contrast, heat pumps seemingly achieve the impossible – you get more heating out than the energy you put in. This is possible because we use energy to move heat rather than converting the energy directly to heat. As a result the apparent efficiency in terms of heat output is greater than 100 per cent. This is shown in the diagram.

The heat pump cycle



Source: Automatic Heating

The ratio of electrical energy input to heat output is called the coefficient of performance or COP – where the higher the COP, the more efficient the heat pump. For the heat pump in the diagram, the COP is 4 units of heat output divided by one unit of electricity input (i.e. a COP of 4).

The COP can be maximised by careful design of the heat pump (efficient compressor, fans and other components) and the use of a thermodynamically appropriate refrigerant.

The key external factor affecting both the COP and capacity of a heat pump is the temperature difference between the evaporator and the condenser. The narrower this temperature difference, the easier it is to transfer the heat, and the more heat we can transfer for every unit of energy input.

This means that in a space heating application, for instance, the heat pump will be very efficient at mild temperatures, but less efficient when it's really cold.

rebate in some states, alongside more commonly known solar hot water systems.

"Even compared to electric or gas-boosted solar hot water systems, heat pump hot water units carry advantages that make them arguably more attractive," says Fletcher.

As well as not requiring solar panels, heat pump hot water units can operate 24/7, and their electrical consumption can be as low as 500–700W.

"They can also make ample use of onsite solar PV (photo voltaic) electricity, supplying on occasions the entire power load required by the unit," he says. "This makes their energy intake 100 per cent renewable."

HEATING IN A PHASE-DOWN FUTURE

Reflecting the HFC phase-down and the HVAC&R industry's movement towards lower global warming potential (GWP) refrigerants, Sanden International has started using R744 (CO_2) in its hot water heat pump system.

R744 offers a number of benefits in this space. It has minimal GWP, is not an ozone-depleting substance, and gets very hot very quickly, allowing water temperatures of 65°C to be achieved without an electric booster.

"At an ambient temperature of 20°C, it has a high coefficient of performance (COP) of 4.5 and uses 1kW of energy to generate 4.5kW of heat – equating to 22 per cent of the energy used by a conventional electric storage hot water system," says Sanden International managing director, Mark Padwick.

But like Fletcher, Padwick says the optimal application for a hot water heat pump is when it can be connected to solar-generated power.

> The HVAC&R industry must upskill itself if the technology's promise is to be fulfilled

"This is due to the low energy consumption and the short re-heat periods required to generate sufficient hot water," he says.

SPACE HEATING

The potential offered by heat pumps for hydronic space heating is also significant, and while still in its infancy here in Australia, it could one day challenge traditional heating solutions.

"Hydronic space heating through the floor or slab has a number of advantages over conventional reverse-cycle refrigeration heating," Fletcher says.

Among these is its ability to provide an even and comfortable heat from the floor up without drying or dehumidifying the air. It also creates no airflows or currents in the conditioned areas, makes no noise, and can offer higher efficiency when properly designed.

"For space heating – particularly for hydronic heating with a slab water temperature around 30°C – efficiencies can be as high as 600 per cent, with typical values around 400-450 per cent," Fletcher says.

IN INDUSTRY

Although heat pumps are generally considered to be a technology for the residential sector, high-temperature industrial heat pumps are slowly entering the market to replace traditional boilers.

Having worked with the Australian Alliance for Energy Productivity (A2EP) on the implementation of demonstration projects showcasing this technology, Pears says heat pumps can compete with gas boilers and furnaces.

But there are some caveats.

First, Pears notes that industrial processes may need to be redesigned because of the greater importance of temperature differentials. And he says when costing heat pump systems, a number of factors must be considered.

"The multiple benefits of heat pump systems need to be factored in as offsets to higher capital cost."

But most importantly, Pears warns that industry training is required if heat pump technology is to be adopted more widely. Plumbers are more likely to have had experience with the technology than RAC professionals, so the HVAC&R industry must upskill itself if the technology's promise is to be fulfilled.

"Training must be extended well beyond traditional approaches, trades and professions," says Pears.

"We are only in the early days of adapting."

Early days indeed, but heat pumps are a technology definitely worth keeping an eye on.

If you've had any experience working with heat pump technology, *HVAC&R Nation* would like to hear about it. Drop us a line at mark.vender@airah.org.au

CASCADING ADVANTAGES

According to Alan Pears, significant advantages lie in the cascading or multi-staging of heat pumps.

"With most refrigerants, the lower the temperature differential between the condenser and evaporator, the more efficiently they work – CO_2 being an important exception," Pears says.

"A reduction of just one degree across the heat pump can improve efficiency by 2–4 per cent. So if two heat pumps are installed in series, with the heat from the first unit acting as the input source of heat for the second, the temperature difference across each unit is smaller and each works more efficiently."

Cascading or multi-stage heat pumps are being used in some supermarkets and industry, as well as some commercial buildings. And Pears notes that where hydronic heating is used, they are emerging in the residential sector also.

"Obviously they cost more to buy, but the efficiency benefits will improve their economics as energy prices increase, and as more people try to get maximum benefit from their solar power generation."