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Blowing hot and cold: Reflecting the potential value of air-to-air heat pumps in UK energy policy

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Introduction

The broader context of a warming world means that to maintain the levels of comfort we are used to and to adapt to a hotter climate and limit the impacts of heat waves, increased use of air conditioning or 'cooling,' which tends to require the use of blown-air systems, will be needed. There are obvious concerns that the increased use of cooling could further exacerbate climate change.[1] However, a pragmatic approach which recognises that heating will still dominate energy use for countries like the UK, and that renewable electricity production can coincide with cooling demand, means this issue should be quite manageable.[2]

But there is another angle to the likely growth of cooling. Cooling systems can normally provide both cooling and heating from one device. Perhaps such 'reversible' systems could create a consumer pull towards wider building electrification.

The potential pull towards heat pumps offered by the expected growth in cooling and the fact that air-to-air systems may offer specific value in certain property types means that policymakers should consider such systems as part of heat pump deployment policies. However, any policy support offered should reflect the likely limits of air-to-air systems and not deflect from the known value of decarbonising existing wet central heating systems. This briefing expands on these issues and looks to provide advice for policymakers working in this area.

[1] Telegraph. (2023, June). *How Britain's love affair with air-con is forcing us back to coal.* https://www.telegraph.co.uk/business/2023/06/13/britain-air-conditioning-energy-coal-power-plants/

[2] Financial Times. (2023, June). *Carbon counter: cool heads needed for air-conditioning conundrum.* https://www.ft.com/content/ae81bdc8-9e52-4c2e-a2a3-d3b7dd34e66e

This briefing[3] considers the potential for air-to-air heating (and cooling) systems to contribute to building-level decarbonisation in countries where wet central heating systems currently dominate. The vital role of air-to-air heat pump systems in countries which already have significant levels of air-blown heating is obvious. This briefing focuses on the UK, but will have similar implications for other countries where wet central heating systems are used.

Wet versus dry

Those of us with radiators or underfloor heating (known as a 'hydronic,' or 'wet' system) have probably never considered getting rid of it. And even though people talk quite happily about transforming the way we generate and use heat, because of climate change and the need to replace fossil fuels, the issue of how we distribute heat in homes has never really been in focus. But perhaps we need to be thinking much more about using 'air-blown' systems and air-to-air heat pumps.

Air-to-air heat pumps are heat pumps which do not use a wet central heating system. In Europe we would generally refer to air-to-air heat pumps as air conditioning — and we are familiar with the blower units which produce hot or cold air, like those we find in hotel rooms and offices similar to the one below.

Moving away from wet central heating may sound controversial, but consider that in the United States air-blown systems (often referred to as HVAC, heating ventilation and air

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conditioning) are the most popular form of heating,[4] and they can also sometimes perform cooling, air filtration and dehumidification. And when looking at the rapid deployment of heat pumps in Nordic countries, air-blown systems dominate.[5] Wet central heating is only really the norm in central and northern Europe and the northeastern United States.

There are some reasons why perhaps that norm should change. But before going any further, some words on types of heating systems. In wet systems, heat is moved around a building as hot water in pipes, and the heat is transferred into a room via radiators or via underfloor heating which heats the space above it. There are two types of air-blown systems:

- Ducted systems are those which use ducts to move warm air from a central plant to wherever the heat is needed.
- Ductless systems take refrigerant — i.e., the heat transfer medium in heat pumps — directly into the space to be heated (or cooled), and in the 'indoor unit' use a fan to warm (or cool) the air in the room by blowing it over the hot (or cool) refrigerant in a heat exchanger. These are the white boxes sometimes seen on walls, often referred to simply as 'internal units.'

The benefits of air-to-air heat pumps

Combined cooling and heating

The reality is that a warming world requires more cooling. While we can reduce how hot the world will get through climate mitigation and we can use passive measures like shading and blinds to limit the need for cooling, we will still need more cooling. A recent review paper[6] highlighted that the UK's National Grid has been assuming up to 18 million UK homes will have cooling by 2050; and that policymakers have barely considered the implications of this.

But it is not straightforward to use cooling via a wet system, it ideally needs to be air-blown. This is because cold surfaces and pipes develop condensation, and we would end up with pools of water around our homes if we allowed pipework, radiators and floors to get too cold. There are options to use wet systems with cooling, but these require large heating surfaces (e.g., with underfloor heating or large wall units) and potentially costly modifications including specific types of emitters which may require an electricity supply and additional pipework. Such systems may also effectively throttle back the cold output to limit condensation, thereby limiting the actual cooling capacity.

However, air-blown systems can be used for both heating and cooling in both ducted and ductless systems. It may therefore be that a growing demand for cooling could lead to the

[4] United States Department of Energy. (2023). *Everything you need to know about home heating.* https://www.energy.gov/sites/default/files/2014/01/f6/homeHeating.pdf

[5] Carbon Brief. (2023, October). *How heat pumps became a Nordic success story.* https://www.carbonbrief.org/guest-post-how-heat-pumps-became-a-nordic-success-story/

[6] Khosravi, F., Lowes, R., & Ugalde-Loo, C. (2023). Cooling is hotting up in the UK. *Energy Policy* 174. https://www.sciencedirect.com/science/article/pii/S0301421523000411#:~:text=Our%20UK%20cooling%20energy%20policy,risk%20assessments%20published%20to%20date

use of more heat pumps as systems installed primarily for cooling, which could lend themselves to also being used for heating.

Potential increased efficiency

Furthermore, the low output temperature of air-blown systems from heating compared to radiators means that in theory air-to-air heat pumps can deliver extremely good coefficients of performance (effectively efficiency), potentially better than air-to-water systems.

Air-to-air systems also often yield lower heat losses as they have no heat exchanger (between the refrigerant and circulating water) in the external unit. There is an air-to-air heat pump on the Danish government's appliance database with a measured seasonal coefficient of performance of 6.2,[7] equivalent to 620% efficient. Typically, an air-to-water heat pump might achieve a seasonal coefficient of performance of 3 to 4,[8] but these figures also include hot water production which generally achieves a lower coefficient of performance than heating. The two are therefore not directly comparable. It's also worth bearing in mind, that public testing data for air-to-air heat pump performance appears to be very limited.

If hot water production and cooling are done at the same time by the same air-to-air unit, overall efficiency can be extremely high, though in reality this is tricky and normally only a feature of larger commercial systems.

Potential lower costs

Air-to-air heat pumps can also be cheap and simple to fit. Refrigerant pipework is generally narrower than for wet central heating systems and blower units can be fitted at a high level in rooms, minimising the use of floor space. I've had a quote for my house for £2,500 for a 'split'[9] system which does both heating and cooling in two rooms. But that system is not going to meet all of my needs. The *Cost Optimal Domestic Electrification* study[10] for the UK government suggested that air-to-air heat pumps could indeed be the most cost-effective technology for certain building types, namely flats and some uninsulated houses.

The limits of air-to-air

Based on what has been said so far, one might presume that a switch to air-blown systems would be a no-brainer and that governments should be going all out for them. There are however a few limits:

- Adding ducted systems to an existing building is extremely difficult, as space needs to be found for ductwork. Retrofitting of ductless systems and associated refrigerant pipework is likely easier but requires the installation of internal units.

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[7] Danish Energy Agency. (2023). *Choosing the right heat pump model.* https://sparenergi.dk/varmepumpelisten

[8] Gibb, D., Rosenow, J., Lowes, R. and Hewitt, N. (2023). Coming in from the cold: Heat pump efficiency at low temperatures. *Joule* 7(9), 1939-1942. https://doi.org/10.1016/j.joule.2023.08.005

[9] In a split system, the refrigerant is piped into a building. In monobloc systems, all of the refrigerant is kept in the external unit and water is used as the heat transfer medium.

[10] UK Department for Business, Energy & Industrial Strategy (BEIS). (2021). *Cost-Optimal Domestic Electrification (CODE).* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1104051/CODE-Final-Report-WHOLE-FINAL-v20.pdf 3

- Split air-to-air heat pumps require refrigerant pipework which goes into the house and (in ductless systems) to each internal blower unit; this is similar to plumbing for water, but requires an 'f-gas' qualified technician.
- The new pipework may also be disruptive depending on its position, and if fitted poorly will create a risk of refrigerant leaks. Freestanding or all-in-one units do not have this issue.
- The growth in the use of propane in monobloc units (not split) as a leading 'clean' refrigerant has undoubtedly led to innovation in heat pump performance and refrigerant sustainability, but this flammable refrigerant is not ideal for split systems where the refrigerant goes into buildings. It's not clear that any split systems currently use ultra-low global-warming-potential refrigerants. Therefore, there are broader refrigerant considerations for air-to-air systems.
- Most air-to-air systems will only produce heating and cooling, not hot water, so a separate hot water solution such as a domestic hot water heat pump may be needed; it should be noted that some air-to-air models do produce hot water but these are currently niche offerings, particularly in household settings. Daikin's combined whole house air-to-air heat pump system with hot water is not yet on the UK market.11
- In practice, there don't appear to be any domestic air-blown systems which provide heating, cooling and hot water and utilise the efficiency benefit of using waste heat from cooling for hot water production. Because cooling demand may be limited in northern climes anyway, it's not clear such as system would offer a huge advantage.

What to do

For most homes, if the owner wants efficient and electrified heating, cooling and hot water production, and doesn't want to move to a purely air-blown heating system, two heat pumps will be needed.

One set-up could include a hot water heat pump alongside an air-to-air heat pump for heating and cooling.

Another set-up might be an air-to-water heat pump which provides hot water and heating using the existing pipework and radiator system with an additional air-to-air heat pump simply to provide cooling. For reasons of cost and simplicity, currently it seems likely that this would be the go-to option for most homes which already have wet central heating.

However, for small homes or flats that don't already have central heating, it might be that an air-blown system for both heating and cooling makes most sense alongside a separate system for hot water, like solar thermal, as shown in this Cornish case study.[12] Smart hot water storage which utilises off-peak electricity may be another technology which would complement air-to-air heat pumps. Perhaps new homes will be built with all-in-one air-blown systems with associated hot water production.

[11] Personal communication with Daikin UK.

[12] Cornwall Live. (2022). *How Cornish households can protect themselves against rising energy bills.* https://www.cornwalllive.com/special-features/how-cornish-households-can-protect-6889196

Data can also help decision-making, yet currently available data on the sales of air-to-air systems to households is poor. UK government estimates[13] suggest the sales of cooling systems are in the region of 10,000 to 42,000 per year in new homes and the same volume in existing homes, but as well as having a broad range, this data also includes 'portable' systems, meaning free-standing cooling units. Furthermore, while cooling systems are technically air-to-air heat pumps in that they pump heat, it's unclear what proportion of these systems were installed for – and are used for – heating. More data on the UK air-to-air market would undoubtedly have value and would support better decision-making.

Policy implications

There are multiple variants of heat pump systems, and the UK's current grant system, like that of many other countries, only provides support for hydronic systems. Such an approach, perhaps rightly, pushes homeowners towards wet systems. There has also been a historic concern that funding for air-to-air heat pumps might simply incentivise cooling and potentially deliver only limited additionality[14] because people may have installed these systems anyway. Technological and market innovation could however make air-to-air systems increasingly important.

[13] BEIS. (2021). *Cooling in the UK.* https://assets.publishing.service.gov.uk/media/614c1c75e90e077a34ed9fb7/cooling-in-uk.pdf

[14] UK Department of Energy & Climate Change. (2014). *RHI Evidence Report: Reversible Air to Air Heat Pumps.* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/371697/RHI_Evidence_Report_-_Reversible_Air_to_Air_Heat_Pumps.pdf

On the other hand, there is an argument that because air-to-air systems are cheap to install, any support offered should be limited. In Ireland, for example, grants for air-to-air[15] are lower than for air-to-water systems.

There are clearly some benefits to the deployment of air-to-air systems, including lower upfront costs than wet systems, potentially reduced disruption for homeowners, and excellent system efficiency – and therefore possible bill reductions. It may also be the case that if a household has installed an air-to-air system for cooling, and that system is reversible, it could be used to provide some clean heating alongside a fossil fuel heating system; a crude hybrid-type system. If air-to-air systems can accelerate the wider efficient electrification of the building stock, on a clear strategic path, policymakers should ensure they are promoting their use as effectively as possible.

The maximum benefits of air-to-air systems are likely to be in houses which don't have wet central heating and where the space available is limited. These could include flats at particular risk of overheating which might benefit from cooling to support health outcomes, and small properties that never had central heating and where it might not be appropriate.

To recognise the value of air-to-air systems, there is clearly a need for more communication on their value, and this needs to sit within wider clean heat and building communication efforts. Our specific policy recommendations are as follows:

- Subsidies and other forms of market support could be made available for air-to-air heat pumps, but they should be carefully limited to reduce the risk of primarily supporting cooling systems and to ensure additionality benefits from public funds. Larger grants (or credits under the proposed heat pump market mechanism) could be made available for whole house air-to-air systems which also include hot water production. Smaller grants (or credits) could be made available for more limited air-to-air systems, and certain types of installation such as standalone units would need to be excluded. A condition of air-to-air system grant funding for homes currently with fossil fuel heating could be the removal of the fossil fuel boiler.
- With the UK government currently reviewing permitted development planning permission for heat pumps, air-to-air systems should be explicitly covered by the review to ensure that planning permission is generally not required for any type of heat pump system.
- Alongside specific support and communications, wider supportive policies – like those outlined in RAP's heat pump policy toolkit,[16] including price rebalancing and appliance standards – would also accelerate the rollout of air-to-air heat pumps. The UK government should expedite plans to rebalance energy prices to support the wider electrification of the economy.

Air-to-air heat pump systems are unlikely to be for everyone in the UK, but with some of the benefits they offer, particularly in small dwellings, and the need for rapid decarbonisation, policymakers should ensure that their value is reflected in the heat pump support policy package, subject to necessary controls.

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[15] Sustainable Energy Authority of Ireland (SEAI). (2016). *Heat Pump System Grant*. https://www.seai.ie/grants/home-energy-grants/heat-pump-systems/

[16] Regulatory Assistance Project, CLASP and Global Buildings Performance Network. (2022). *A policy toolkit for global mass heat pump deployment.* https://www.raponline.org/knowledge-center/policy-toolkit-global-mass-heat-pump-deployment/

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