net-zero research network

A Network+ for the Decarbonisation of Heating and Cooling

Heat pump trial workshop report

25th January 2023, Energy Systems Catapult, Birmingham

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Executive Summary

An in-person workshop about heat pump trials was held in Birmingham, 25 January 2023, funded by the EPSRC Network for the Decarbonisation of Heating and Cooling. The key purposes were to share expertise, to explore best practice in running trials, identify gaps in knowledge and propose ideas for further heat pump trials. In addition, to strengthen the network of heat pump manufacturers, energy companies, researchers, practitioners, government and research funders. Over 50 people attended the day, with representatives from all sectors. The workshop began with a series of presentations to set the scene in terms of existing research knowledge, experience of current trials, UK policy and government funded-research and international experience. This was followed by facilitated discussions, the findings of which are captured in a workshop report. It was agreed that while there is enough evidence that good quality heat pump installations can deliver comfort at reasonable cost, there are many detailed questions about heat pumps which require further investigation to help accelerate mass uptake. There is experience of good practice in designing and running trials which can guide us, some of which is well-documented, but also some gaps in knowledge, particularly around problems encountered, which frank discussions in workshops can help to address. Ten different future trial themes were outlined; these included proposals for research on flexibility options, impacts on electricity networks and improving the user experience.

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Background, aims and format of the workshop

The UK government has set a target for 600,000 residential heat pump installations per year by 2028 – this stands in stark contrast to the current installations of less than 50,000 per year. While it is widely agreed that heat pumps will be a very important component of the transition to low carbon heating, it is less clear what role research, and research trials, should play in enabling this transition, at least economic, social and environmental cost.

There have been, and continue to be, a number of heat pump trials in the UK. Most of these are small in scale and of limited duration. They explore different aspects of HP technical and economic performance, system design issues, user satisfaction, changes in heating patterns and so on. Recently there has been a focus on the intersection of flexibility and heat pumps – exploration of the benefits to the electricity system and users of reducing on-peak demands of heat pumps. However, trials often fail to reach their potential, with under-recruitment of households and failure of communication and monitoring systems being a common experience.

The aims of the workshop were

1. To share experiences from previous and current UK heat pump trials, with the aim of creating a common understanding of best practice.
2. To identify knowledge gaps that further heat pump trials could fill.

The workshop opened with expert presentations, followed by discussion of six topics by participants in facilitated sessions. The topics and facilitators were:

- What we haven't learned, Gavin Killip, University of Oxford
- What's missing from heat pump trials to date, Bryony Parrish, University of Oxford,
- Developing the next trial, Jake Barnes, University of Oxford
- Best practice for heat pump trials, Sam Hampton, University of Oxford
- Common challenges with heat pump installations and trials, Daniel Logue, Energy Saving Catapult
- Who are the research users? Jacki Bell, University of Durham

The topics overlapped to some extent – as did the discussions – so the reporting here brings together elements from different discussion groups for clarity, and to reduce repetition. There was consensus on many of the themes raised, with similar ideas voiced by different people from different sectors. Where a view was in a minority, this is indicated in the text.

Over 50 people attended the day, with representatives from national and local government, academia and research organisations, manufacturers and the heat pump supply chain, energy companies and research funders.

Summary of expert presentations

Participants were welcomed to the event by **Dr Andy Smallbone**, Durham University, the Director of the Network for the Decarbonisation of Heating and Cooling, which organised and hosted the event.

Dr Tina Fawcett, Oxford University gave an overview of the history of UK heat pump trials and briefly introduced some current trials. Common challenges in trials have included household recruitment, data quality and trialling flexibility successfully. She concluded that we know that good quality ASHP and GSHP installations perform well technically and householders are generally very satisfied with thermal comfort. However, there are still many questions to be explored via trials, which this workshop will help identify.

Dr Matthew Aylott, Electrification of Heat Senior Policy Advisor, BEIS set out the UK government's approach to decarbonising of heat. He began by setting out the challenge – heating is responsible for over a third of national carbon emissions. Key elements from the Heat and Buildings Strategy were introduced. The government's approach is to; stimulate demand through public investment and regulations; support investment through a market-based mechanism to be introduced in 2024; and enable HPs through policy, including on skills and cost-reduction. The importance of trials for policy making was set out, with specific examples of how trial results have improved policy design and delivery. Previous and current government-funded trials were listed. The presentation concluded that HP will have a major role to play in meeting decarbonisation targets, and that trials will have a critical role in informing policy and demonstrating the efficacy of new technologies or approaches.

Tim Bailey, Samsung, spoke about Samsung's experience of heat pump trials. Heat pumps are different from other consumer products as the consumer experience is dependent on the running costs, installation and maintenance partners, not just the manufacturers. Innovation is highly collaborative. Samsung have been involved in trials looking at heat pump integration with smart services, and with another on improving the installation and maintenance experience. It's important to trial heat pumps in the real world -not just in 'real world settings'.

Dan Logue, Energy Systems Catapult presented findings from the Electrification of Heat Demonstration Project. The project used a variety of communication methods to recruit participants, achieving 742 installations, 80% of which replaced gas heating. The installation costs varied considerably depending on delivery contractor, manufacturer and other factors. The customer journey was complex, with plenty of points at which customers might withdraw. Householders not accepting the disruption of an installation was by far the biggest barrier. Quality Assurance has proven useful, as has heat pump monitoring which allowed remote diagnosis of problems and optimisation of performance. DNO connection processes may delay installation. Results show installations are possible in all home types and ages, but some are more challenging.

Caroline Haglund Stignor, Heat Pump Centre, c/o RISE talked about HP experiences from beyond the UK: Sweden, Europe and the IEA perspective. Caroline began by explaining the R&D work the International Energy Agency undertakes on heap pumps, via a Technology Collaboration Programme (TCP). Sweden (10.5M inhabitants) has about 1.5M residential heat pumps and 30% of heating demand is supplied by heat pumps. The transition away from oil, and towards electricity, district heating and biomass has been as result of consistent decisions and a policy mix since the 1970s. In Europe there has been a strong rise in heat pump sales in many countries, e.g. market growth of

50% in Finland in 2022. Sales of heat pumps in France are more than 10x those in the UK. To reach carbon reduction goals, IEA states that strong policy in support of heat pumps is needed in many countries, including a range of policies on technologies, training, taxation and consumer information.

Common challenges with heat pump uptake

Common challenges with accelerating the uptake of heat pumps were identified – these form the backdrop against which heat pump trials are undertaken. Participants were not specifically asked to come up with solutions to all of these challenges, but several were provided in the 'best practice' session. Where there is broad agreement on solutions, it seems unlikely a trial is needed to test them – the challenge is ensuring their adoption in practice.

Customer-related

Key barriers to the adoption of heat pumps include: high capital cost of heat pump retrofit – especially when compared to a boiler replacement; a slow or no return on investment; disruption during installation. In addition, customers need to look into repair and maintenance contractors, which is more complex than for a gas boiler; conversely the levels of support required for heat pump customers is much higher than boilers, with aftercare needed as standard. Finally, potential customers often come into discussions with negative perceptions due to adverse press / publicity surrounding heat pumps.

In terms of solutions, evidence and experience from previous and current trials suggest that:

- It is essential to put the customer / trial participant at the heart of the process
- Commissioning routines and handover is essential to get right and iterate. Different processes work best for different users (e.g. Youtube video, 1:1 explanation of controls)
- Support beyond commissioning is important too. Retrofit for the Future ran for 2 years, and at the end users were concerned about who they could ask for help with controls once trial finished.
- 1:1 handholding is essential throughout installation. But it doesn't really matter WHO does it. It could be a local champion, housing advisor, or somebody working for manufacturer or energy supplier.
- Having a user champion is a good model. Somebody within the customer / participant cohort who is trained and acts as liaison and representative for the user group. They can also advocate for those unwilling to adopt.

In addition, design is important: heat pumps should look attractive. Controls also need to be well designed, robust and reliable. Supplying just an app for control, especially apps which don't get updated, is insufficient.

In order to create a more positive environment for HP adoption, better education is needed to make people aware of the low carbon heating choices they will need to make over the next 5-10 years. People will need to be prepared for some disruption in this transition (in addition to pursuing innovations in technology and organizational improvements to reduce disruption).

Planning and policy

There are a number of local barriers to installation of HPs which can include: local planning regulation restrictions (particularly around noise and visual intrusion); the difficulty of finding a site for the heat pump outdoors, particularly in certain building types; DNO notification processes can be slow and can cause delays in permission to install. Research to develop guidelines on noise and aesthetics issues (e.g. how much noise, where, when is too much?) could help ease the first of these issues.

There is a lack of cohesion when it comes to national HP support policy, this means industry gets mixed signals and therefore investment decisions (time and monetary) are put off. Why invest now in re-training if there is likely to be another 10 years of business installing boilers? The contribution of HP towards energy security needs to be recognised by policy makers (although, they also require resilience).

Supply chain - manufacturer through to installer

It is widely agreed that there is a lack of skilled / trained HP installers and engineers. There is also concern about the ageing of the workforce. Currently manufacturers provide much of the training and accreditation for installers – this may limit installers and consumers to certain products.

One specific problem identified was oversizing of heat pumps. The cause was identified as design protocols, including MCS guidance. Oversizing can lead to difficulties in getting DNO connection permission, and additional noise and space challenges. It could also reduce performance in situ.

There was concern about whether accurate predictions are being made on energy costs for heat pump use, based on extrapolating heat pump operation from existing use of gas central heating. Accurate figures would require prediction of routines of using HP as well as various technical aspects that influence heat pump performance and running costs.

Two contrasting solutions to the skills shortage were proposed: to upskill engineers or to simplify the work tasks to avoid the need for full re-training. This could be done by providing a consistent set of tools / information, via an app for example, which helps with the tasks the installers aren't familiar with or don't want to do, such as system design. More generally, interpersonal skills were identified as important for installers and customer-facing people, in addition to their technical skills, not least because they are often the most important source of advice to consumers on how to get the best from their HP.

The BEIS 'Electrification of Heat' project is enabling experimentation with different business model approaches, as exemplified by different contractors. For instance Eon took a vertically integrated approach, recruiting customers and delivering the installations, while others sub-contracted to bodies such as Retrofit Works and local organisations. There are pros and cons for both. The Eon model allows for more control (e.g. timelines) but may be more expensive. The other approach might help to build local capacities and strong partnerships.

Known challenges in heat pump trials

Key issues across current heat pump research trials were identified, and classified into different phases of the trial. Workshop participants were not specifically asked for solutions to these problems – but where identified, these are included. Future trials also need to take these issues into account and to learn from the solutions identified.

Trial design

Longer-term data collection on performance is missing. Installations are not re-visited, and we do not have data about medium and longer-term experience over 5-10 years.

Many trials do not have a control group, i.e. properties which don't have heat pumps or the trial solution. In addition, often there is no data on heating energy use, usage patterns, comfort levels etc. prior to the HP being installed. Both of these factors limit our ability to interpret the results of HP trials. The solution would be that trials should include pre- and post-installation monitoring of

energy use (electricity and gas), indoor temperatures, and qualitative measures of occupant comfort as standard.

Trials are frequently non-representative, sometimes despite their intention as target and cost and time-driven trials end up excluding some groups. For example, few trials are conducted in shared households (HMOs) or Hard to heat properties.

Conduct of trials

The trial period is often less than planned because there are many challenges to starting on time (e.g. partner contracts, participant recruitment) but trials need to finish on time due to funding rounds, so this squeezes any trial or monitoring period.

Monitoring often does not deliver the data intended for a variety of technical, organisational and social reasons. Installing enhanced monitoring provides a challenge, particularly if this has to be delivered by heat pump installers who aren't used to dealing with monitoring equipment. To reduce the risk of monitoring failures impacting the project's key learning objectives, one route is to include equipment or data collection redundancy. This could be as simple as taking regular spot temperature or meter readings, in case smart metering or continuous temperature sensors fail.

There are aspects of some trials that few people understand, typically the backend/algorithmic elements in, say, flexibility trials. This makes it harder to hold some partners to account, if they are the only experts; it's also harder to understand and communicate results of the trial as a whole. To reduce this risk, increasing independent quality assurance may help with the accountability question for complex elements of trials.

Working with people

Recruiting enough participants to complete the trial, particularly where the offering is less than "a free heat pump", is a key challenge. Once the HP and monitoring equipment is installed participants might alter the monitoring equipment, without meaning to disrupt the trial, which can reduce data quality. Unexpected participant behaviour is often not accounted for in scoping trials

Data collection and reporting

Classic challenges around data collection and reporting include

- Poor quantitative data quality
- There is no common heat pump monitoring or data protocol
- Open access datasets not published as standard practice
- Failures / horror stories are not published, there is a bias to only reporting positive experiences

There is a clearly identified need for common metrics for heat pump performance – that help to understand both how heat pumps perform, and why. These should/could be useful for both experts and end users – potentially increasing end users' understanding of their HPs performance and empowering them to address it – including through being able to share this information with third parties. Other participants strongly emphasised that, to be useful, heat pump performance data must be both standardised and accessible.

In order to learn from failure as well as success, reported findings should include what doesn't work, as well as what does, and qualitative case studies as well as aggregated quantitative results.

There was a suggestion that digital performance twins (i.e. digital models of the real world) should be developed to complement heat pump trials, as these are expensive to implement. This could make better use of existing data from BRE, and some participants felt the range of data available on existing of different types of heating (e.g. gas central heating, electric storage heaters) would mean

that end users' experiences of thermal comfort when living with heat pumps could be fully represented in such a model.

Some participants suggested that it would be useful to test HP performance in physical houses built for experimental purposes, but without people, to distinguish between technical (building fabric, heating system) and social (user routines and practices) influences on HP performance in use. Others felt that separating social and technical analysis can be problematic in itself.

Ideas for future trials

Ideas for future trials emerged in most discussion groups, whether directly or indirectly as a result of identifying what's missing in terms of deployment of heat pumps (e.g. 'user awareness of the technology'), and then thinking about how these missing elements could be investigated in trials. Many different ideas emerged – these are grouped into themes below.

The network impact of HPs

Experience of high-density deployment of heat pumps, the grid impacts of this, and how it varies by location. This could be important to identify target areas for heat pump deployment, including as part of local area energy planning more broadly. Upcoming projects funded under BEIS' Heat Pump Ready programme will help to address this question.

To what extent is flexible operation of HP possible, considering the type of flexible operation (what electricity system services are being delivered) and its timing? In particular, is peak demand reduction possible at the coldest times, when electricity demand by HP and associated grid impacts would be highest? Participants observed that at such times HP are operating constantly, suggesting limited opportunities for pre-heating or charging of dedicated thermal storage, and questioned whether flexible operation would ultimately be able to displace the need for network reinforcement

In addition, consideration is needed of how HPs can interact with PV and EVs, at household and network level.

Flexible use of HP

There is an assumption that HPs will be used flexibly within future dynamic electricity systems. Yet, quite how this will transpire is unclear. If the UK government plans to require all new HP installations to be 'smart ready' by 2025 what do we need to know? How might industry prepare? As part of understanding flexibility, some felt there had been too little focus on the role of tariffs.

Suggested trial topics on flexible use of HP could include:

- How might the Internet of things transform monitoring in the future?
- Testing new control systems, e.g. where immediate control is removed from the end user; more complex/sophisticated control systems
- Testing ideas like switching off HPs for 5-10 minutes rather than 1-2 hours at a peak point. Is this more acceptable to customers?
- Test potential for cooling
- Develop and test market segmentation, what types of users are there? What kinds of control do different users need/require?

Understanding the appropriate balance between HP and building retrofit

Participants highlighted the need to understand the optimum balance between HP capacity and building fabric retrofit, considering heating performance in coldest weather, associated total costs (both capital and running costs), and electricity system impacts. Understanding this would help to inform policy design, which currently emphasises support for HP installation with little to no

provision for retrofit. How should policy be designed, and policy spending distributed between direct support for HP installation, and for building fabric retrofit?

Understanding HP impact on vulnerable households

We need to more fully understand the range of potential impacts on lower income households or those in fuel poverty, including changes in running costs, and health impacts – either positive or negative. This assessment should also consider the impact of future scenarios such as further energy price changes. As there has been some experience of HP deployment in social housing it may be particularly important to consider impacts on private renters, who may not have control over decision to install HP, and who may have less support available to them than social housing tenants. This may become more pressing if changes to the calculation of EPC ratings makes HP installation a route for landlords to meet minimum standards for EPC ratings. However, engaging the most vulnerable to take part in trials will remain difficult.

Intervention points

More attention needs to be given to engaging households with heat, with the customer journey once they have decided to adopt a HP and in lead up to adopting a HP. Some of the issues identified require research, but not necessarily via field trials.

- How can trials explore potential to foster societal uptake of upgrades such as installing low temperature radiators, prior to HP adoption?
- EPCs - What needs to change to support HP deployment? How can this be achieved?
- How to link home retrofit work to preparing for HP installation? What are the linkages?
- How to help households to adapt to living with HPs, and who fulfils this role?
- What is customers' willingness to switch (in different segments)?

Improving Performance

HP SCOP needs to be improved beyond 3 to make a real impact and reduce running costs below those of an efficient gas boiler. Testing improved HP system design to deliver such improvements could include details such as: optimising control strategies, whether to install a buffer. Remote monitoring and optimising services should also be tested. In addition to further technical trials, understanding the socio-technical nature of deployment is important. More research effort should be directed towards the socio-technical analysis of use to understand why performance isn't as good as expected. In addition, there could be consideration of whether lower performance but lower capital cost (or greater acceptability) would be a worthwhile trade-off. Optimum technical performance may not deliver the best outcome for the customer.

Different HP technologies: Air-to-air and hybrid HP

Some participants suggested the UK should consider air-to-air heat pumps given their successful deployment in other European countries, potential use for cooling (which may become more important in the future) and possible demand reduction benefits of moving away from central heating (heating rooms in use). Trials of air-to-air HP could test 'plug and play' models, test the impact of zonal heating, investigate what air circulation issues emerge. Some wondered about hybrid HPs (i.e. ASHP / gas boiler) – earlier interest in these, via government trials or support, has diminished. Is there a case for further trialling this solution?

Tackling disruption and control

More attention needs to be given to new ways to install HPs that reduce disruption and teaches/introduces users to HPs. There is more disruption when extensive work is needed to radiators, hot water cylinders, pipework – do we focus enough on lower disruption options for these elements of the system? Trials could include processes where people are moved out during

installation, like the Energiesprong approach. Previous trials have shown the importance of those who engage households (middle actors / intermediaries), link between various actors, do the hand holding. These roles should be designed into future trails and then examined. What do they do? What works? How could the role be improved? Who are the most suitable candidates to take on this role(s)? More generally, trials could also look at different modes of project coordination – roles, functions and interactions, and how to improve the functioning of the whole supply chain.

Understanding and improving user engagement with HP

Need better understanding of how to improve end user awareness of and engagement with HP. Participants suggested that as well as general awareness and uptake of the technology, this should include users' engagement during use and their lived experience. Other participants suggested that we still need to understand what actually constitutes thermal comfort when using a heat pump. For example, how is thermal comfort affected by differences in e.g. radiant heat when using a lower temperature heating system, or any differences in perceived control over heating? How do patterns of use affect comfort? How does building fabric (e.g. insulation, thermal mass) affect HP user experience? What different concepts of comfort and usability do people hold?

Societal engagement

There are currently trials looking at how scalability can be achieved through social learning / social marketing, e.g. HP Ready programme. But social influence doesn't have to be local/geographical, it can also be digital – this could be trialled.

More experimentation needs to be directed towards the way in which publics are engaged with HPs and heat decarbonisation more broadly. Ideas include:

- Enabling people to have experience of HPs, including site visits via open home networks, e.g. Superhomes, or more extensive experience of staying overnight in, say, an Air BnB with a HP
- Explore different engagement techniques and lead organisations (public, private, third sector/community) what is the wider societal response to different approaches (c.f. direct impact on household participants and tech performance)?
- Explore how and in what ways customer knowledge and behaviour change in the neighbourhoods where trials take place. How do perceptions and knowledge evolve, in what ways, why and how, for those not directly involved?

Research users

Chris Artist from Northern Powergrid, Andrew Angus from Eon and Isabella Panovic from EPSRC talked about trials from a research user and funder perspective. Chris and Andrew also talked about the advantages and learning from taking part in collaborative trials.

Attendees were asked to identify the range of potential users for heat pump trial research. The table below shows the wide range of stakeholders who could benefit from this research. This can inform who helps shape the trials, who is involved in delivering them and to whom the results are communicated.

Policy/Funders	Supply Chain	Consumers/Customers
BEIS Innovate Other Govt Depts (DEFRA, MHCLG) Research Councils Members of Parliament Select Committees Government Ministers CCC	Heat pump designers Manufacturers Suppliers Installers Maintenance – Plumbers/Gas Engineers Retrofit Coordinator Local Authorities/Planners DNOs Consultants	Housing Associations Developers Builders Retrofitters Citizens Community energy groups Consumer Advice Groups Energy Savings Trust
Research Community	**Education/Skills**	**Accreditation/Standards**
Academics Catapults RCUK Citizen science (*Individuals sharing their experience*) Public Forums Social media Open Access research Open energy monitor https://openenergymonitor.org/	Skills providers/HE/FE Colleges Universities – Mech/Elec/Heating Engineers/Architects Media/Journalists Social Media NESTA Curriculum developers	Building Regs ISO/BS Standards MCS Insurance companies? BRE HBF

Online Resources

Copies of the presentations and library of previous email trials can be found on a Miro board and on the Decarbonisation network website.
https://miro.com/app/board/uXjVP1xvgSw=/
https://net-zero-research.co.uk/network-hc/