Summary of findings from heat pump flexibility expert workshop

Fifty experts representing heat pump manufacturers, electricity distribution and transmission, energy suppliers, trade associations, government, consultancy and academia contributed to a day of discussion aiming to answer the following question:

> In 2035 we plan to have a decarbonised electricity system, which will require demand flexibility to keep system costs down. **What will be the role of heat pumps** in providing that flexibility?

This document summarises the outcomes of the 9 group discussions which took place on the day. The first five topics below relate to the role of heat pumps. The final topic highlights supporting elements which will need to be in place for heat pumps to carry out this role.

Headline summary:

A. Elements of an agreed vision emerged. The vision is that heat pump flexibility will be: widespread, highly automated, limited by not negatively affecting thermal comfort, incentivised mainly by electricity prices, and useful for hourly energy arbitrage and network management although not in all circumstances.

B. Some elements were not agreed upon, including: the role of enabling technologies such as thermal stores, how to address equity issues, and whether/how customers should feel part of the system.

C. The vision relies on several key assumptions including high levels of customer acceptance, effective financial incentivisation, and heat pumps and heating systems correctly interacting. More work is needed to understand these areas.

1. What are the use cases for heat pump flexibility?

- Participants from multiple organisations expressed the view that most of the monetary value of shifting heat pump operation was in wholesale energy arbitrage, to balance supply and demand on a several-hourly basis.
  - Many homes may be able to switch off a heat pump without loss of comfort for around 2 hours, which could contribute significantly to smoothing the winter evening demand peak (around 3 hours).
  - Integration of renewable electricity more generally was also seen as a use case, although this is limited to situations where e.g. wind power varies over half hourly timescales, not situations in which there is no wind for several days.

- The other main use case is for electricity network balancing, which participants felt would be of lower financial value than wholesale energy arbitrage.
  - Participants representing distribution networks stated that:
    1. In new developments, heat pumps will not be required to run flexibly, since the distribution networks will be specified correctly to incorporate heat pump demand.
    2. In areas containing existing homes, in some cases reinforcement of the low voltage network is the cheapest option rather than procuring flexibility; in other cases the opposite may be true. It was emphasised that often reinforcement at a substation level is not particularly expensive.
    3. It may be possible to use heat pumps for more than solely peak demand management – this is something distribution network operators are currently considering, and will depend partly on whether it is found that customers are happy with short notice periods for flexibility events.
  - The topic of transmission network constraints was not greatly discussed

- Some participants pointed out cases in which heat pump flexibility may not be required due to other sources of flexibility:
  - For example, one participant predicted that in certain areas with a large number of flats, storage heaters would provide all the required flexibility while heat pumps were left to run normally instead of flexibly, "*having to work against their nature*".
  - Another participant pointed out that by 2050 there will be a lot of grid scale multi-day/week energy storage in the electricity system, and predicted that this could also be used for hourly shifting at lower cost than demand flexibility. If this were the case then heat pump flexibility would be a temporary solution whilst the UK is transitioning to a decarbonised energy system.

In summary, heat pump flexibility has several use cases and most participants envisaged it being used. However, some thought that it would be unnecessary in various situations where other forms of flexibility could be used.

2. How much heat pump flexibility is envisaged by 2035?

- Most group discussions arrived at the conclusion that participation in heat pump flexibility would be widespread, with 50-90% of domestic heat pumps participating.
- Some participants addressed the question by predicting how many households will not run their heat pumps flexibly – one stated that 20% are "wedded to" a two-burst heating approach, and another brought survey evidence in which 20% of respondents "were against the principle of it at all". Other proposed reasons for not running heat pumps flexibly were: ability to afford expensive electricity at peak times, and social factors (vulnerability, inability to shift heating based on presence of young children) which would render households unable to provide flexibility.

- In order to provide an estimate of nationally aggregated heat pump flexibility in physical units (e.g. GW, or GWh), the groups used evidence from presentations earlier in the day, which found an average per-household contribution of 0.75 kW. Assuming 20% of homes have heat pumps and a maximum of 90% of these households participate, and that they all participate at once, this leads to an upper bound of around 4 GW.

In summary, the dominant view at the workshop was that most domestic heat pumps will participate in flexibility, which could aggregate to several GW depending on heat pump uptake and coincidence of flexibility participation.

3. What will heat pump flexibility look like?

Overall mechanism

- Heat pumps will be turned up/down or on/off for a period of time, during which internal conditions will be maintained using either the thermal inertia of the building or a dedicated thermal store.

Length of shifting

- Without extra storage being installed, participants envisaged space heating being shifted for around two hours, and hot water production for up to 12 hours.
- The two hour value came from a belief from participants that for most of the year heat pumps can switch off from space heating for two hours without the temperature dropping enough for the household to mind. A subset brought empirical research evidence of this and the rest reported what they had heard from others, previously or at the workshop. As a notable exception, the NEDO trial (2014-2017) found an acceptable heat pump switch off period of only one hour for many households, who were living at low temperatures.
- Longer shifting can be achieved using a thermal store. The role of in-home thermal storage was disagreed upon, with some participants stating it will be a "key part" of integrating renewables and managing peak demand, and others concerned about space or cost.
- Another way to lengthen the load shifting period may be to preheat the building; this is currently being tested in the HeatFlex trial. The implications of preheating for comfort and energy use require more work to understand.
- Most participants thought that heat pumps could not shift or drop space heating operation at the coldest times of year, when they would be running constantly at full output. From a network perspective this was identified to be a time when most flexibility would be required. This dilemma was not resolved at the workshop.
- Responses to the question *How long will heat pumps shift their operation for?* were driven by household thermal comfort limiting what can be achieved, as opposed to an expectation from e.g. electricity system stakeholders that heat pumps must provide a certain amount of flexibility.

Control of shifting

- There was widespread agreement that heat pump operation would need to be highly automated in order to gain the high levels of participation described above.
- By 2035 a large proportion of heat pumps in the stock will be smart-enabled, and the power to the heat pump will be accessed and controlled by either the heat pump manufacturer, the energy supplier or a different flexibility provider; thus heat pumps will be remotely controlled.

Financial incentives

- To achieve high levels of participation, it was agreed there needs to be a financial incentive for the customer, such that participating in flexibility is the cheapest way of running their heat pump. What this financial incentive looks like, how it brings together the use cases of energy arbitrage and network management, or how large it has to be, were not clear. Half hourly pricing (static and dynamic), availability payments and turndown payments were all mentioned, and there was agreement that the payment mechanism would be different for different customer bases.

Arrangement

- Many participants thought the offer to the customer would be made through the energy supplier. There was not consensus on where the liability would fall if an actor who is not the heat pump manufacturer caused damage to the heat pump by running it outside of its ideal operating parameters (e.g. high temperatures, suddenly shutting down power), nor how likely this scenario would be.
- How heat pump flexibility would work alongside other domestic flexibility was not resolved. One participant illustrated this issue: "*If you have an EV and a heat pump and you choose a tariff with overnight charging, you then might shift how you use your heat pump as well, because the peak price will be really high for you.*"; other participants highlighted that night time preheating has been found to be uncomfortable for householders. A topic that was not discussed was the role of home energy management systems, and to what extent heat pumps will be controlled by the same external party as other domestic loads.

In summary, participants envisaged a highly automated system that could shift heat pump demand a couple of hours in return for a financial incentive, except at the coldest times of year. There are multiple areas to be resolved regarding payment, liability and the role of thermal storage and preheating.

4. What are the implications for customers?

- In line with the above highly automated view of heat pump flexibility, little engagement for the customer was envisaged after an initial period of setting their preferences, e.g. temperature bounds, or times which they did not want to be controlled remotely. Participants felt that customers should, however, be provided with an override.

- A strong message emerged that the high levels of heat pump flexibility anticipated could only be achieved if householders stayed comfortable. Ongoing trials are currently trying to ascertain what temperature levels are comfortable amongst their samples. However it was felt that households would differ in their comfort 'envelope', and that it was therefore important not to enforce a pre-programmed band of temperature based on an average, but a tailored service. This would take a while to work out: it was felt that customers were not going to be able to communicate their preferences in advance but that remote controllers should either learn preferences as customers override, or customers could input their temperature preferences and update them as they experience and live with heat pump flexibility. Some participants additionally thought customers should not notice heat shifting being carried out.
- Multiple participants presented research evidence that hot water provision at the time of day demanded by the household cannot be compromised, and that failing to deliver this could mean customers no longer engage in flexibility at all. All heat pumps which provide hot water have a storage tank, so shifting hot water heating is possible and is a useful form of flexibility. A heat pump load shifting strategy must consider when to heat hot water as well as when to run space heating.
- There were differing opinions on the necessary level of understanding from customers, both in terms of the bigger picture of why shifting was being carried out, and also how to operate their own heat pump. Some participants felt that customers should feel engaged in the new flexible energy system where they know that their demand shifting helps the electricity system run more efficiently and everyone's bills are lower. Others thought they did not need to know that, only how much money they would save by participating. Interest and understanding was expected to vary across households and within households in any case.
- Participants wanted the arrangement to be fair; however what this would look like was not resolved within the workshop. The issue raised most often was that temperatures dropping may not be acceptable for some vulnerable groups, who would then get hit with very high electricity prices at peak times. A second issue was the need for people who do not have smart homes or digital literacy having to engage manually, creating extra work for them.

In summary, participants envisaged a system which delivered hot water at the right time and kept participants comfortable by operating in the background, informed by households' preferences and requirements but not interacted with apart from that. There is still work to be done on how to not unfairly penalise households for whom this arrangement will not work.

5. What are the implications for heat pumps and heating systems?

- It was agreed that heat pumps will need to be able to turn on, off, up and down according to external signals. This will become compulsory for new heat pumps in 2026/2027 if the smart mandate is brought in as intended, although it will not necessarily mean that this functionality is used.

- The above flexible operation, as opposed to constant operation, means that heat pumps will run less efficiently, due to several factors e.g. higher flow temperatures, possible addition of more space heating storage into the system. There was some concern expressed by heat pump industry representatives that this would make heat pumps more expensive to run. Other participants addressed this by reiterating that off-peak electricity prices need to be low enough (or equivalent financial incentives) to account for e.g. flow temperatures being higher, to incentivise flexible operation.
- Some participants believed that there should not be damage to or decreased lifetime of the compressor as long as the operator controlling the heat pump knows what they are doing. However it was acknowledged that there was a possibility heat pumps could be damaged by being operated in ways for which they had not been tested.
- Participants had different views on who should remotely control heat pumps but the predominant view was that it did not matter as long as the correct protocol was used to enable interoperability.
- Representatives from the heat pump industry agreed that heat pump size should not be increased in order to facilitate participation in flexibility. Although larger heat pumps could warm the home up more quickly after a period without heat pump operation or more quickly charge thermal storage before a period of high electricity price, increasing heat pump capacity would be detrimental overall. This is because heat pumps are already oversized for most of the year's thermal demand so further over-sizing would compromise efficiency.
- It was felt by participants that the heating must be thought about as a system wider than the heat pump. For example one participant noted that a thermostatic radiator valve could negate a heat pump's attempts to preheat a room, and two participants mentioned radiator sizes as a limiting factor in how responsive a heat pump can be. How this system approach can be implemented to ensure the provision of intended flexibility was not discussed.

In summary, participants did not envisage significant change in heat pump design but did foresee a change in how they are run and by whom they are controlled, as well as a need to set up the whole heating system for flexibility.

6. What supporting elements must be in place to achieve the vision?

This section was not discussed as a topic itself, but is created from points made across the whole day. As such it is likely to be incomplete but is a starting point for future discussion of what may be needed.

- **Markets**: half hourly pricing – which will be enabled by forthcoming half hourly settlement – was seen to be a necessity for heat pump flexibility. However it may not be sufficient as suppliers may still not market flexible tariffs to most customers.

- **Customer advice and engagement**: a consistent message was deemed necessary, as opposed to conflicting advice from installers advising customers to run heat pumps constantly and flexibility providers encouraging and on-and-off style of operation. There was debate over whether heat pump installers should be the main point of contact regarding flexibility.
- **Customer protection**: A regulator representative described how a new regulatory regime will be introduced in the next few years, with licensed flexibility providers. The smart mandate will also require interoperability such that dissatisfied customers can switch to a different flexibility provider.
- **Data sharing**: Three examples are given here. The ESO will need to work out what granularity of data it needs visibility of for which use cases, DNOs will require better monitoring at substations (but are not anticipating requiring appliance level data), and remote heat pump controllers will require internal temperature data in order to not breach temperature limits.
- **Building fabric improvements**: were viewed as an enabler of heating flexibility, but not necessary for it.
- **Evidence base**: most trials had recruited early adopters of heat pumps, and a need emerged for research in households representative of mass market future heat pump adopters, particularly regarding acceptability of remote control and flexible operation. Further areas for research included how to ensure flexibility was not hindered by settings elsewhere in the heating system, and whether the building fabric alone could allow enough shifting for the major use cases in most homes (with or without preheating) or whether extra thermal storage would be necessary on a large scale.

About CREDS

The Centre for Research in Energy Demand Solutions (CREDS) was established as part of the UK Research and Innovation's Energy Programme in April 2018, with funding of £19.5M over five years. Its mission is to make the UK a leader in understanding the changes in energy demand needed for the transition to a secure and affordable, net-zero society. CREDS has a team of over 140 people based at 24 UK universities

CREDS is funded by UK Research and Innovation, Grant agreement number EP/R035288/1

www.creds.ac.uk

@CREDS_UK

www.linkedin.com/company/credsuk/

About H+C Zero Network

A Network for Heating and Cooling Research to Enable a Net-Zero Carbon Future (H+C Zero Network) was established in October 2020 UK Research and Innovation (UKRI) to maximise the impact of UK-funded research and innovation in the field of the decarbonisation of heating and cooling. The Network aims to bring together researchers, policy makers and industry partners across the sector, through funded workshops, conferences and secondments which in combination will enable stakeholders and funders to come together to share their progress, new knowledge and experiences.

net-zero-research.co.uk