Conceptualising the drivers influencing domestic heat pump performance in the UK through systems thinking

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Conceptualising the drivers influencing domestic heat pump performance in the UK through systems thinking

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Abstract: The UK Government has committed to the annual installation of 600,000 heat pumps (HPs) in existing houses by 2028 as part of its Net Zero strategy. However, there is a gap between predicted and in-situ HP performance. The aim of this study was to offer a deeper understanding of the socio-technical parameters influencing HP performance in the field and address the emerging enablers of high HP performance in the domestic sector.

Systems thinking was utilised as the integrating framework for the interpretation of the qualitative and quantitative data collected through field monitoring and in-depth site investigations on 21 case studies across the UK. The collected material was inductively analysed and the results were fed into a series of interlinked causal-loop diagrams, specifically focusing on the parameters and feedback processes that are likely to influence HP performance.

The analysis identified seven interconnected focal areas influencing HP efficiency and energy consumption. The structure of the final cumulative systems thinking qualitative model, revealed important feedback structures and served the identification of four high-leverage interventions.

The work mapped for the first time the complex network of the parameters influencing HP performance based on an extensive range of interacting boundaries and achieved new insights into the requirements for well-performing HPs.

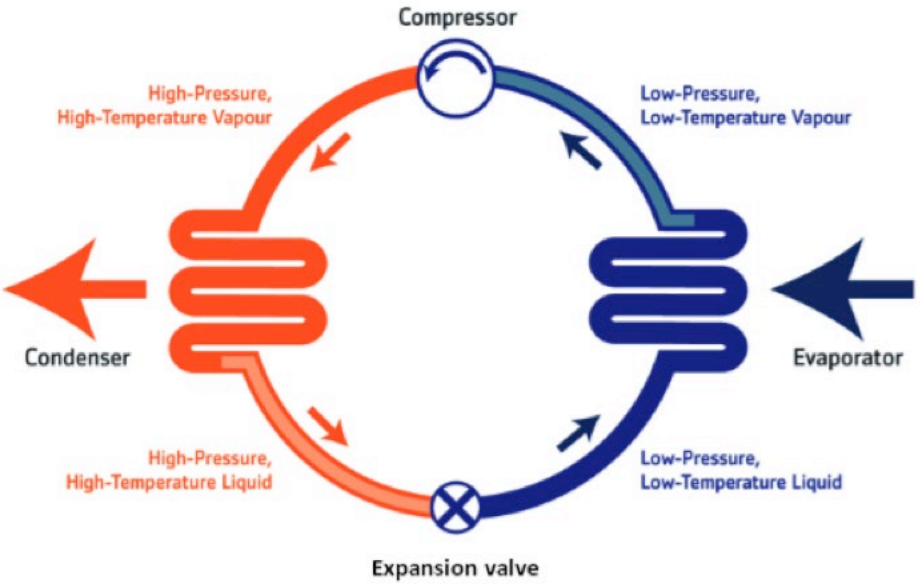
Introduction

Heat pumps (HPs) can generate up to 4-5 times more heat than their electricity input

- Key technology for the UK’s Net Zero target by 2050
- CCC called for 19 million HPs by 2050 (CCC 2020a)
- UK government committed to installing 600K domestic HPs annually by 2028 (HMG 2020)
- By comparison 27,000 HPs were installed in 2018 (EHPA 2021a)

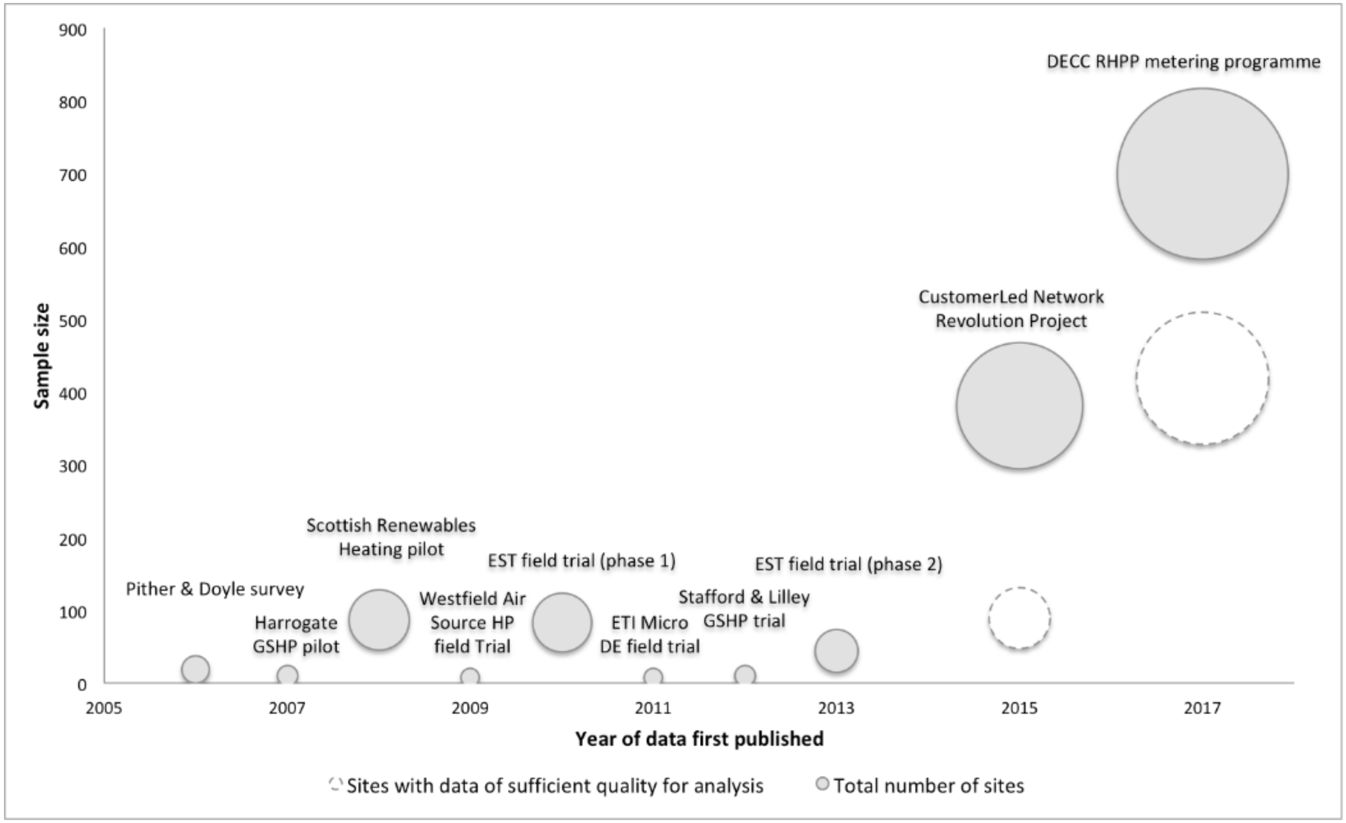
Background

- HP services: SH and DHW
- Operational principle:
  - heat transfer from a heat source (ground, air) to a heat sink with the help of a refrigerant pumped through an evaporation-condensation cycle.
  - Carnot ideal thermodynamic cycle, where HP efficiency depends on sink temperature
- Real life performance depends on a wide range of influencing parameters, including building fabric efficiency, operation patterns, installation quality.



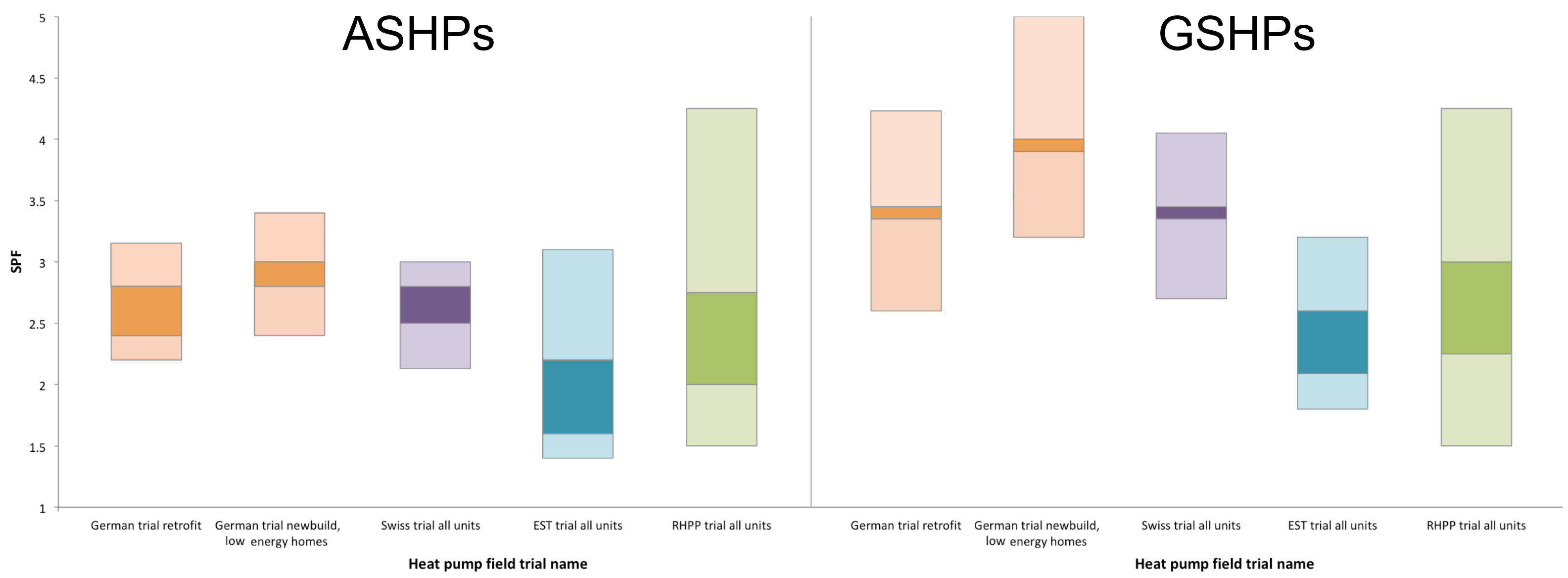
Background: UK field trials

- Little publicly available UK data until recently. EST conducted the first large-scale domestic HP field trial (2009, 83 HPs) and the RHPP field trial was the largest monitoring study in the UK (2011, 699 HPs).



Background: UCL field trials

- Improved RHPP performance in comparison to the EST field trial.
- The comparison with European field trials showed that some HPs can perform as well as in other European countries but there is large variation in performance.



Background: Main efficiency and energy consumption influencers

PERFORMANCE GAP

Variation in installation practices

Dynamic user behaviour

Rebound effect

Ownership

Temperature lift

Design and installation quality

Building fabric heat loss

System complexity & understanding

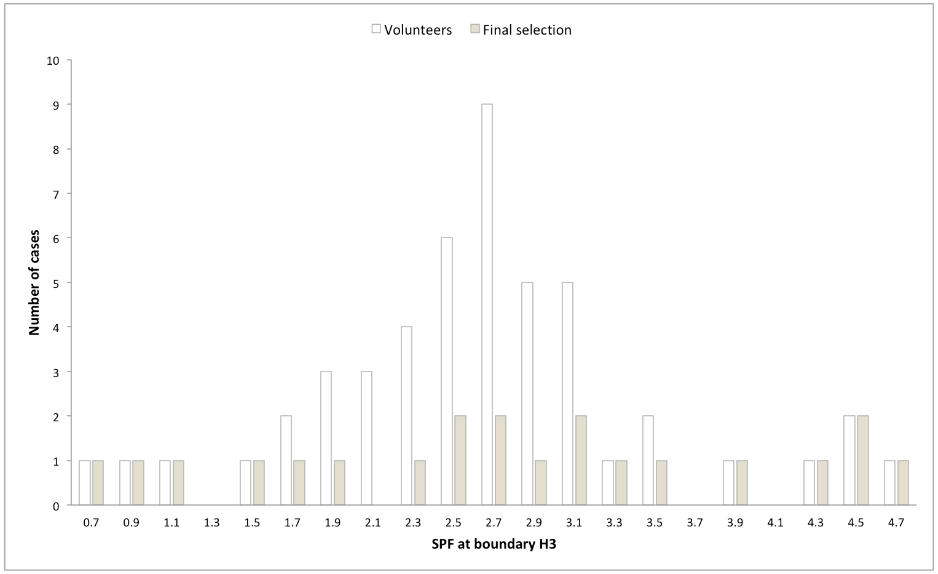
Supplementary heating

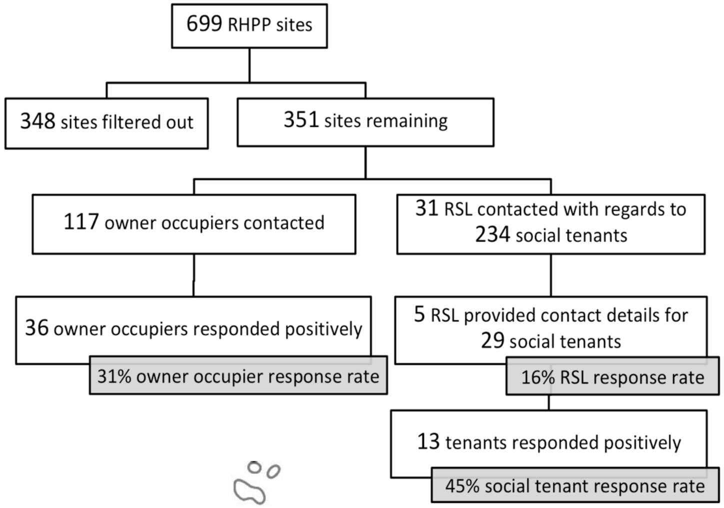
Modes of operation

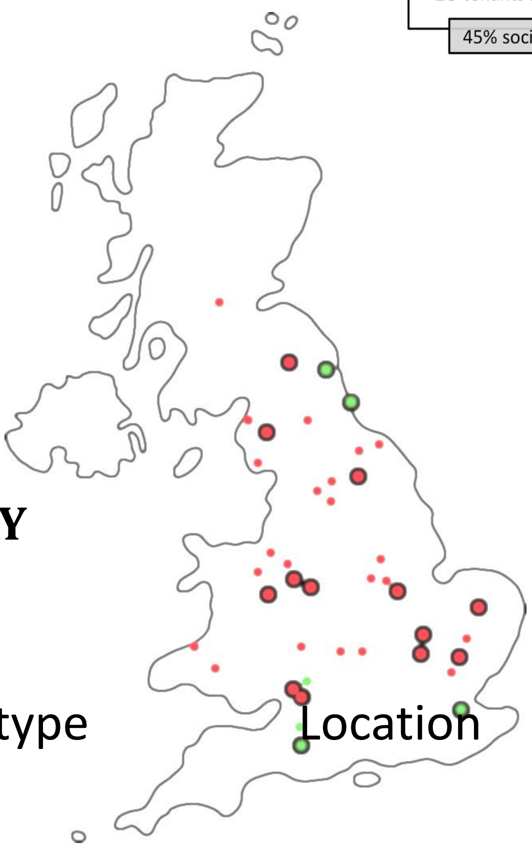
The rebound effect

Methods

MULTIPLE CASE STUDY SELECTION CRITERIA: PRIMARY







CASE STUDY SELECTION CRITERIA: SECONDARY

Ownership

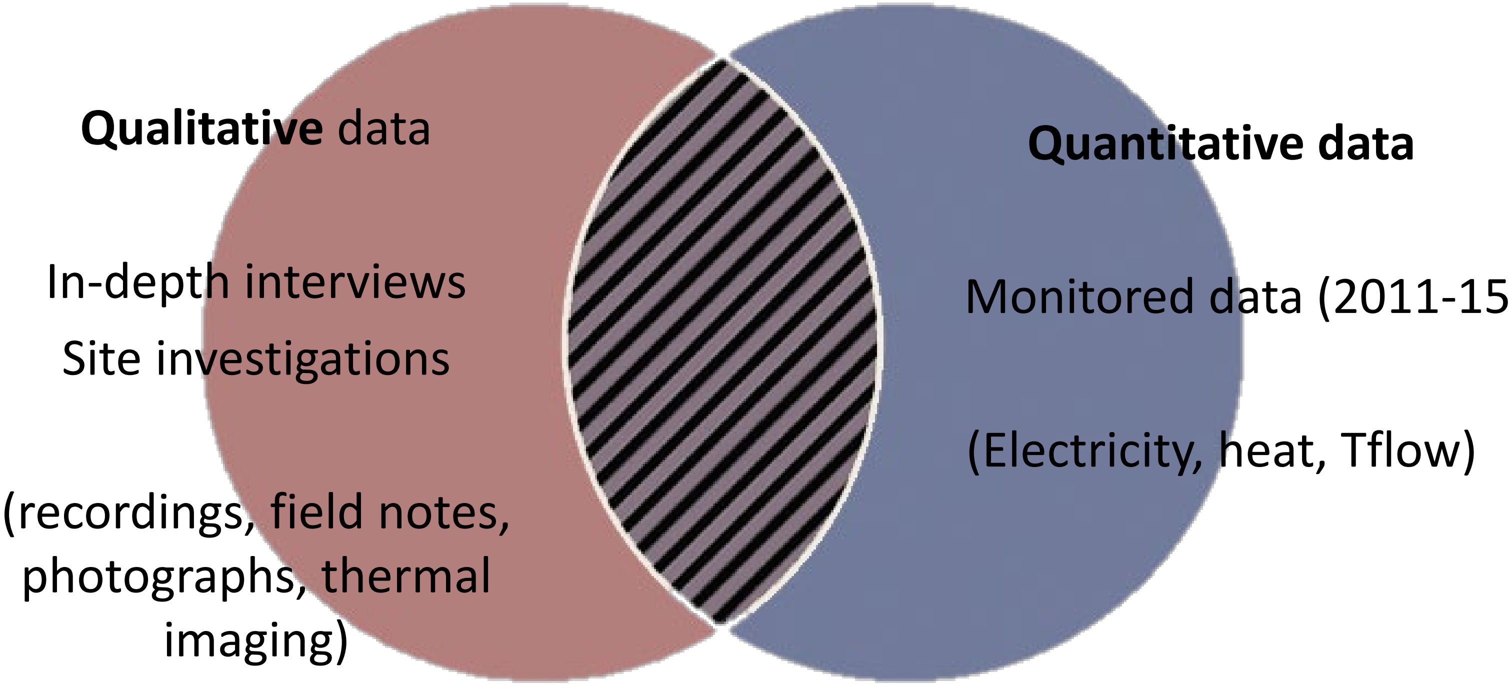
Emitter type

HP type

Location

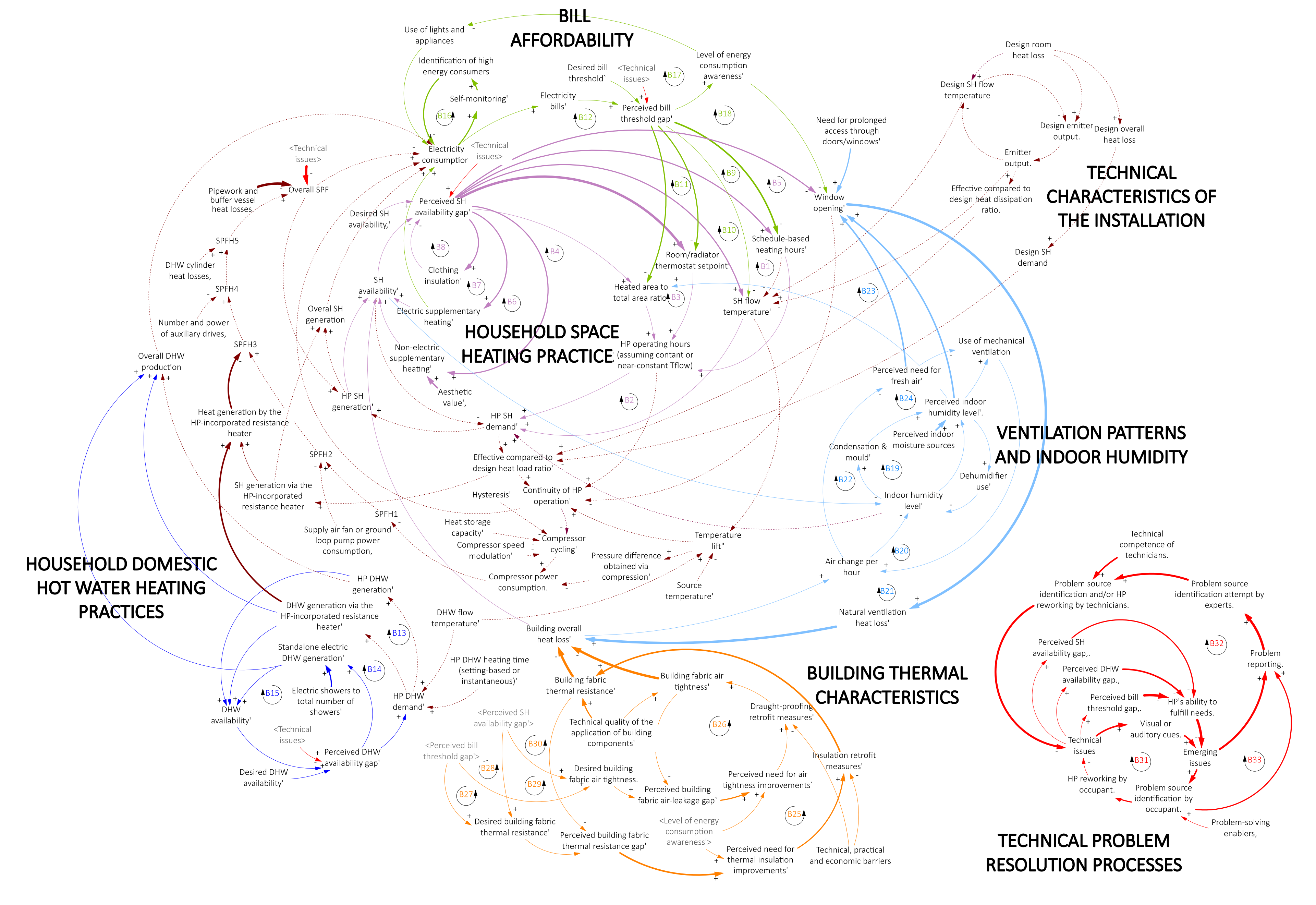
Methods

MIXED METHOD APPROACH

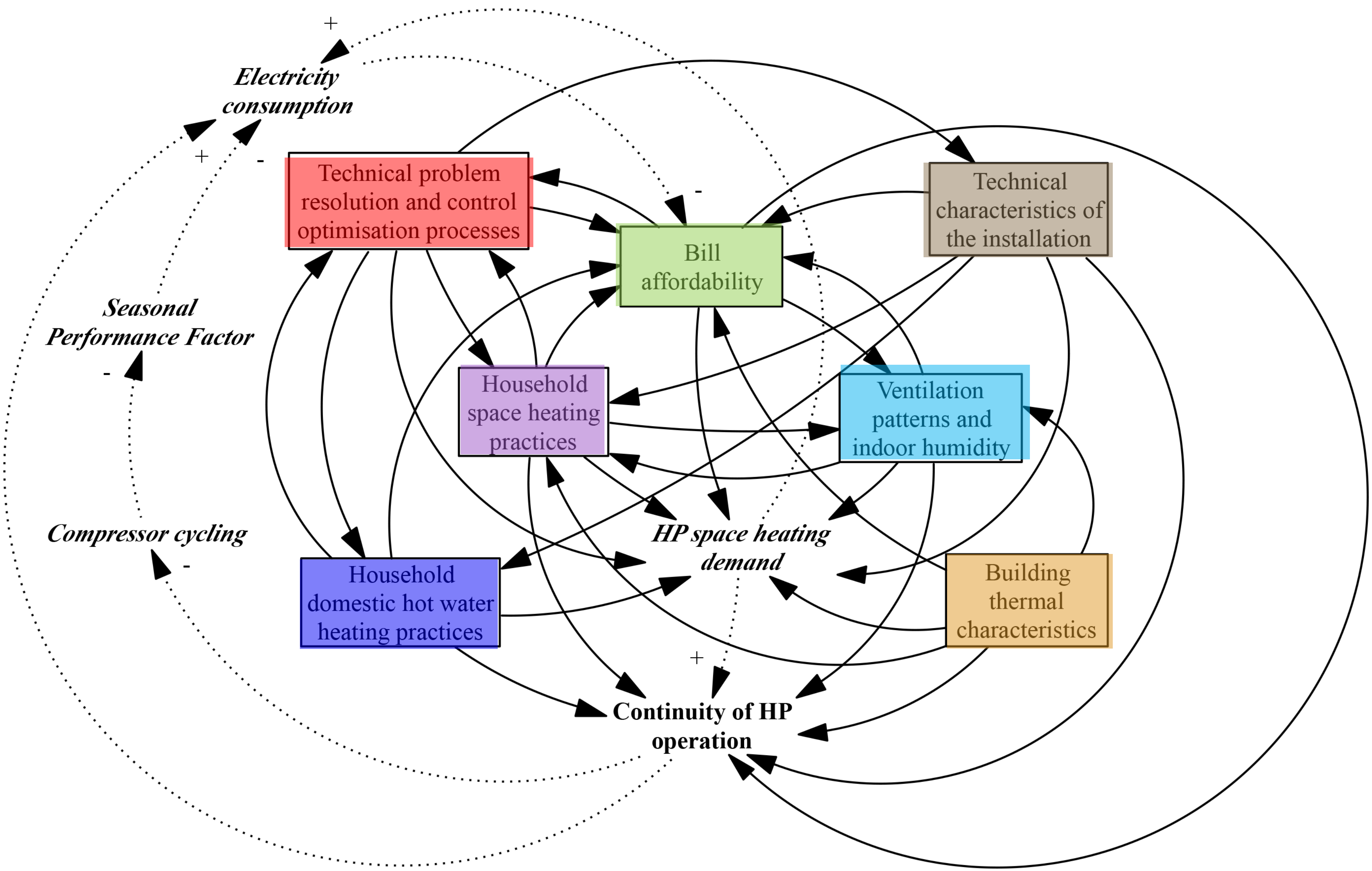


Thematic analysis → Inductive coding → Systems thinking

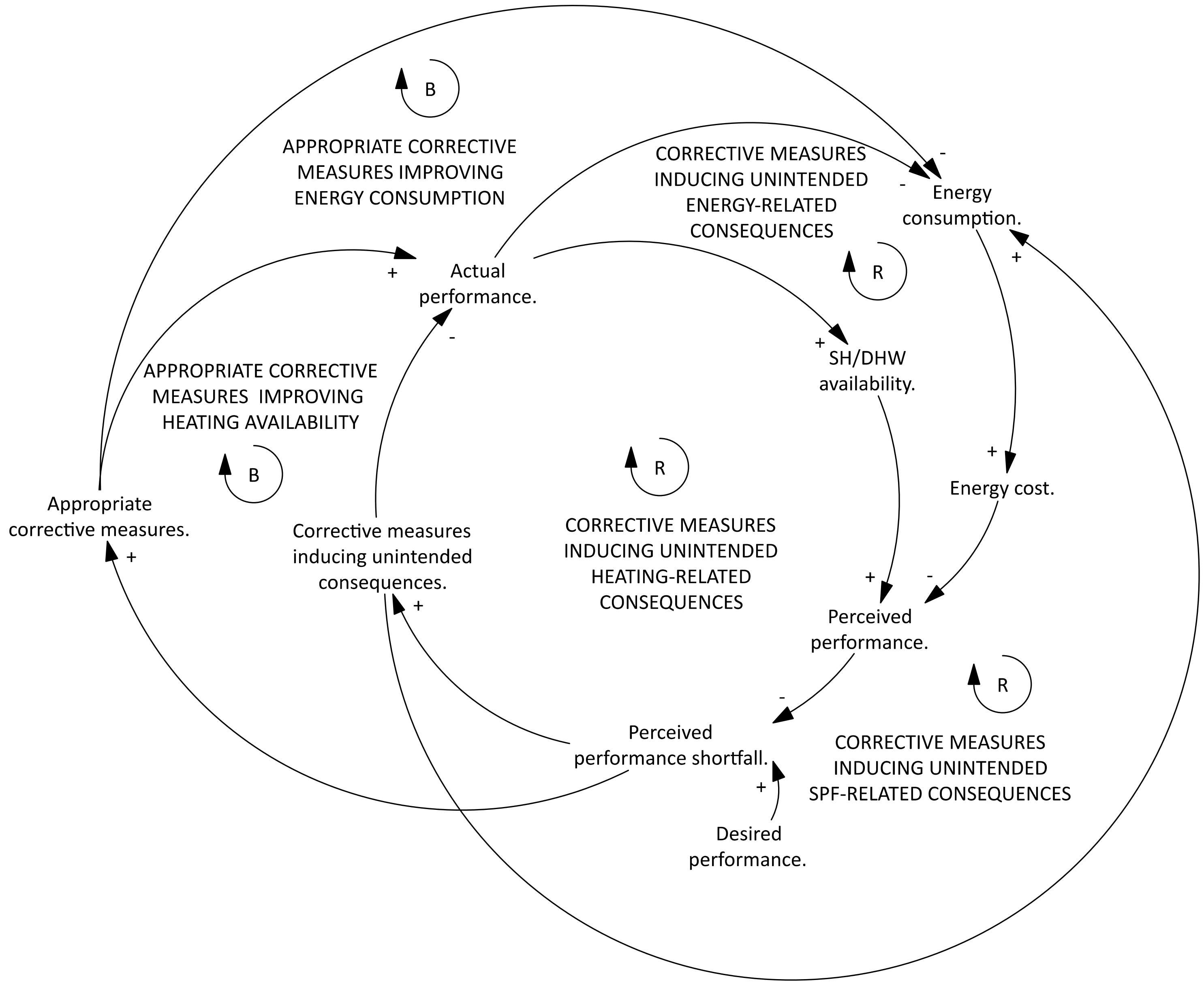
Aggregate CLD



Simplified causal diagram



Summary causal diagram



Findings

HP performance relies on an extensive network of complex socio-technical system interactions.

KEY PERFORMANCE INFLUENCING VARIABLES

Technical issues implying poor technical competence

HP control adjustments and standalone supplementary heating methods

Actions taken to reduce energy bills, presenting unforeseen interconnections

Heat loss uncertainty associated with ventilation + buildings characteristics

Leverage points

1. Ensuring quality installation and appropriate control through behavioural change

2. Enabling feedback on system performance to raise awareness and enhance existing feedback loops.

3. Allowing the incorporation of smart controls to enable additional feedback loops

4. Careful reconsideration of the rules governing HP installation

Key message

Overall, the priority should not be the generation of marketable products but quality installations that will lead to well-performing systems. Only then should a higher uptake of the hp technology be considered. Prioritising quality over quantity is expected to lead to a lower initial uptake of a higher proportion of well-performing installations, which in turn is likely to stimulate market growth. However, this process will take time.

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